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HANDBOOK ON FISH CULTURE
in the
INDO-PACIFIC REGION

Based on a manuscript by S. L. HORA and T. V. R. PILLAY
prepared in co-operation with
the Fisheries Division of FAO

FISHERIES DIVISION, BIOLOGY BRANCH
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1962

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CORRIGENDA

TO

HANDBOOK ON FISH CULTURE

in the

INDO-PACIFIC REGION

page 6, line 6	:	read "deal" as "dead"
page 11, line 19	:	read "larvae" as "larval"
page 13, line 3	:	read "Coleron" as "Coleroon"
page 14, line 7	:	delete comma after "rice"
page 16, line 36	:	read "proved as "provided"
page 19, line 17	:	read "gree" as "free"
page 22, line 16	:	read "Karimoen" as "Karimeen" and "Tallathi" as "Pallathi"
page 26, line 9	:	read "character in character to" as "character to"
page 27, line 2	:	read "scales" as "scale"
page 27, line 24	:	read "epiphitic" as "epiphytic"
page 31, line 2	:	read "pons" as "ponds"
page 31, lines 11 and 12	:	read "epiphytic plankton" as "epiphytic organisms"
page 31, last line	:	read "aboe" as "above"
page 33, line 24	:	read "fe bly" as "feebly"
page 36, line 9	:	read "(1 mm)" as "(1 mm diameter)"
page 37, line 39	:	read "Sym:" as "Other common names:" and "India" as "Indian"
page 39, line 26	:	read "Purveral" as "Puveral"
page 40, line 19	:	read "adults" as "adult"
page 40, line 37	:	read "brans" as "bran"
page 43, line 27	:	omit comma after "Baja"
page 50, line 30	:	read "curiculus" as "curriculus"
page 50, last line	:	underline "Thynnichthys sandkhol"
page 51, line 4	:	read "Cyprinidae" as "Siluridae"
page 51, line 27	:	read "Osphonemus" as "Osphronemus" and "Osphenemidae" as "Osphronemidae"

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, February 1962

PURPOSE OF THIS SERIES

This is one of a series of Technical Papers (see inside front cover) dealing with various aspects of the work of FAO Fisheries Division, Biology Branch, including the review of pertinent information on particular topics, to meet requests for assistance, for presentation to technical and scientific meetings, etc. Extra copies can be obtained by application to:

Biology Branch, Fisheries Division
FAO, Rome, Italy

PREPARATION OF THIS DOCUMENT

Prepared at the request, and as a contribution to the work, of the IPFC. First draft by S.L. Hora assisted by T.V.R. Pillay, revised and edited by Biology Branch, Fisheries Division, FAO. Provisional Edition issued as unnumbered FAO/ETAP document, August 1955.

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Pillay and consultants
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FAO Regional Fisheries Officers
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IPFC Panel A (Inland Fisheries)
Other regional fisheries organizations concerned with fish culture
Fish culturists in the Region
FBCB "short all" mailing list

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Revised edition of Hora, S.L. (1955). Deals with both theoretical and practical aspects of fresh and brackishwater fish culture in ponds, lakes, canals, reservoirs and paddy fields.

FOREWORD

It has long been the desire of the Food and Agriculture Organization to provide for the workers who do not have ready access to libraries a handbook on the cultivable fishes of the Indo-Pacific Region, which would provide a review of the fish cultural practices - many of them empirical - used in this area. The need for such a handbook has been reiterated in many sessions of the Indo-Pacific Fisheries Council (IPFC). In 1952, the late Dr. S.L. Hora of the Zoological Survey of India, was entrusted with the preparation of such a book. Together with Dr. T.V.R. Pillay he worked for several years on this compilation. The manuscript was edited by Mr. W.H. Schuster, former Fisheries Biologist with FAO, and issued in provisional form for use at the Third International Inland Fisheries Training Center, conducted by the Government of Indonesia and FAO in cooperation with the IPFC at Bogor, Indonesia, in 1955.[1]

The provisional edition was subsequently reviewed by the Biology Branch of this Division and then by a selected group of fisheries workers, who recommended that certain changes be made and that the handbook be issued in final form. Acceptance of this recommendation posed a somewhat difficult problem. On one hand, it was desirable to furnish the fish culturists of the region with as much information as possible; this demanded the production of a rather voluminous book, and hence, one which would be costly to reproduce. On the other hand, it was important that the distribution of the handbook be wide and that it be made available at little or no cost to the many fisheries departments, scientific institutes and fish farmers of the region. Satisfaction of these opposing demands contributed to the delay in the appearance of the present edition. The matter has been resolved by using the xerox process and issuing the handbook within the series FAO Fisheries Biology Technical Papers (see inside front cover and back of title page) as a contribution by the Biology Branch to the work of the IPFC.

Although a considerable amount of additional information on fish culture in the Indo-Pacific Region has been derived since the original manuscript was completed in 1955, no attempt has been made to incorporate it into the text. However, particular attention is called to new developments in the use of hormones to induce spawning of those fishes which normally refuse to reproduce in captivity. Attention is also directed to the work performed at the Fish Culture and Research Station at Malacca, Malaya on the development of all male hybrids of Tilapia as a means of preventing overpopulation by this fecund genus.[2]

No book of this kind can be "up to date". It is therefore suggested that the reader uses this handbook, which presents basic information of value to fish culturists in the Indo-Pacific Region, as a standard sourcebook and to supplement the information in it by his own search of current literature.

D.B. Finn
Director, Fisheries Division

[1] Report on the Center by W.H. Schuster issued 1956 as FAO/ETAP Report No. 489. Texts of lectures presented at the Center issued as unnumbered ETAP documents, in two volumes, in 1960 and reprinted in 1961.

[2] See, for example especially: (1) Atz, James W. and Grace E. Pickford (1959) The use of pituitary hormones in fish culture. Endeavour, 18(71):125-9. Reprinted as Occ. Pap. Indo-Pacif. Fish. Coun. 59/11.

(2) Hickling, C.F. (1960) The Malacca tilapia hybrids. J. Genet., 57(1):1-10.

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INTRODUCTION

The importance of fish as a source of protein for human consumption is well known.

In a number of the densely populated countries of the Indo-Pacific Region the production of meat and milk is very small in relation to the needs of the inhabitants. Fish as an article of diet is of great importance because it is easier to culture fish in ponds than it is to raise herds and flocks of livestock. Even so, the present production of fish is by no means sufficient to provide all the protein requirements of the region.

A few of the Indo-Pacific countries have brought fish culture to high standards, the average yields per unit area of inland waters being much larger than they are in the region as a whole, and the efficiency and effectiveness of the operations are such that fish are available at economic prices.

It is the purpose of this bulletin to describe the methods that have been evolved to improve pond culture, and thus to enable other fish farmers, through advisory and extension services, to emulate practices that have proved profitable in similar areas of the region.

In doing this, mention is made of suitable species, of some of the limited investigations that have been conducted to obtain more precise information on several aspects of the industry, of fish foods and feeding, selection of breeding stock, diseases and pests, and of various control measures.

The Fisheries Division of the Food and Agriculture Organization is assured that the production of edible and acceptable fish can be greatly increased and, when this is done, that the nutrition levels of the people in the region will be raised.

Improved and enlarged enterprises dealing with natural resources bring in their wake various ancillary trades and services, and these provide employment for many who are not directly engaged in the enterprises. Expanded inland fisheries, conducted on sound lines, will inevitably lead to increased demands for workers in the transport, processing, materials, equipment and marketing undertakings that serve the fish culture industry.

GENERAL INFORMATION

The Area Embraced

The Indo-Pacific Region covers a vast expanse of the eastern portion of the world and contains more than half its population. Very few attempts have been made to survey the inland waters of the region and very little is known about the fisheries resources of some of the countries.

The data in the accompanying table are based in the main on estimates, some of which, in fact, are little better than guesses; nevertheless a rough idea can be obtained from the figures presented of the areas at present known to be under fish cultivation and of the potentialities in the countries named.

History

Fish culture as a commercial enterprise in the Indo-Pacific Region owes its inception to the Chinese and even today the fish culture practices followed in many of the countries of the region were either copied from the Chinese or inspired by them. The earliest clear record in Chinese literature is said to be "The Classic of Fish Culture", believed to have been written by Fan Lai in 475 B.C. Although his account of carp culture in China is inaccurate, it does show that fish farming on a commercial scale was practised in his time. Chow Mit of the Sung dynasty in his book "Kwei Sin Chak Shik", written in 1243 A.D., described in detail the transport of small carp fry in bamboo baskets. In "A Complete Book of Agriculture", written in 1639 A.D., Heu described the collection of carp fry from the rivers and the methods of rearing them in ponds. With the experience gained through generations and with infinite patience and attention to details, the Chinese have brought fish culture to a very high level of development. Those Chinese who migrated to Malaya, Formosa, Indonesia and Thailand carried with them the traditional knowledge of carp culture and established the industry in those countries. They took carp fry from China every year and reared them, and inspired the local people to take up fish culture. The Chinese also developed the culture of milkfish on an intensive scale in Formosa.

The common carp, which is probably a native of China, has been exported to several countries all over the world and its culture has achieved a very high degree of perfection. The association of species with a view to utilizing all available food resources in a pond, appears to have been first developed in China. Even though the industry has been in existence for several centuries, scientific investigation of the methods has gone by default and it is only during recent times that the desire to change fish culture from its empirical status to the plane of a scientifically based enterprise has arisen. Fish culture in Indo-China has also been practised for many centuries. The utilization of Siluroid fishes for culture in bamboo enclosures in running waters appears to be an innovation developed in Cambodia. Even though stocking of the catfish Pangasius in ponds was practised in Thailand in ancient days, fish culture on an extensive scale has only recently been started. Several Chinese and Indonesian fishes have been imported for the purpose.

The origins of fish culture in India and Pakistan are largely unknown. Eastern India, particularly West Bengal, and East Pakistan are areas where fish culture is conducted on a large scale. Undoubtedly the industry must have been developed thousands of years ago. Khona, the daughter-in-law of Varahamihira, recommended the cultivation of vegetables on the banks of fish ponds, which is a clear proof that fish culture was practised during that period. In Kautilya's "Arthasastra", written somewhere between 321 and 300 B.C., a secret means of rendering fishes in a reservoir poisonous in times of war is described (Book XIV, Chapter I, pp. 478, 479), which indicates that fish were

Estimated Area of Cultivable Inland Waters in the Indo-Pacific Region

Country	Fishponds		Natural lakes	Artificial lakes, reservoirs, tanks	Salt or mangrove swamps suitable for fish culture	Lagoons and estauries suitable for fish culture	Wet rice fields		Total inland waters	Area of arable land	Total area of country	Percentage of inland water to total area of country
	Fresh water	Brackish water					Without fish culture	With fish culture				
	ha.	ha.	ha.	ha.	ha.	ha.	ha.	ha.	ha.	ha.	ha.	ha.
British Borneo	-	-	-	50	195,000		17,500	-	212,550		19,100,000	1.11
Burma	-	-					510,000	-		8,754,000		
Cambodia	120,000	-	350,000	500		72,000	1,400,000	-				
Ceylon	-	-	-	8,000	-	117,000	350,000	-	547,000	1,469,000	6,600,000	8.29
Formosa	10,318	112,921	1,500	10,000			520,000	8,000				
Hawaii	-	850	-		-							
Hong Kong	130	60	-	214	1,200	5,700	8,080	200		15,584	10,000	15.58
India	337,980	2,671	725,783	179,943	121,166	264,444	5,762,792	1,619	7,396,398	123,820,000	316,100,000	2.34
Indonesia	9,000	110,000	335,000	27,000	6,000,000	8,500,000	4,500,000	67,000	19,548,000	11,000,000	149,200,000	13.10
Japan	617	-	21,000				2,991,100	8,500	3,021,217	5,992,000	38,200,000	7.90
Korea (South)							1,226,400	-		1,954,144		
Malaya	150	-		500	300,000	-	314,500	45,500	660,650	2,129,000	13,530,000	4.88
New Guinea (Au)	-	-	80,000	-	500,000	100,000	-	-				
New Guinea (N)	-	-	82,130	-			-	-		10,000	40,000,000	
Pakistan	105,000	24,600	30,100	68,500	305,200	424,000	43,400	12,000	1,012,800	21,000,000	94,300,000	1.18
Philippines	50	85,000		230,000		500,000					29,741,290	
Singapore		253	-	-	-	-	-	-	253		70,000	0.36
Thailand	100		25,700						6,161,000	4,751,000	50,000,000	12.37
Vietnam	25,000	2,000	3,000	2,300	14,400	54,025	4,067,990	1,550	4,170,065	3,200,000	32,800,000	12.71

cultured in reservoirs at that time. King Somesvara, of the Chaluklya dynasty, in his encyclopaedic work, "Manasollasa", compiled in 1127 A.D., describes methods of fattening fishes in the chapter on Matsyavinoda or angling. However, no detailed ancient compendia on fish culture comparable to the Chinese classic have so far been discovered in India.

Fish culture had mostly been restricted to the eastern part of the Indo-Pakistan sub-continent until about the end of the 19th century. During the British rule some enterprising Englishmen started to develop the culture of sport fishes in some hill streams. Finding the ecological conditions in these streams very similar to those in their native country, they were successful in establishing the trout in areas like the Nilgiris. This was followed by similar successful efforts in other mountain areas such as Kashmir, the Kulu Valley, and the high ranges of Travancore. With the formation of fishery departments in some of the states, the culture of both sport and food fishes received a fillip. As a result of the food situation created by the World War II, great attention was given to fish farming as a means of producing cheap animal protein to feed the population. Research and extension services are now giving high priority to this enterprise in India and Pakistan.

Trout culture was started in the hill streams of Ceylon in the closing years of the last century to provide sport for anglers. Even though a large number of ponds and lakes existed in the island, very little attention was paid to their utilization until recently. The gourami introduced into the island about 1910 has established itself in the natural waters and is now caught in the wild state in many places. In an all-out effort to increase fish production in the island, several exotic species such as the Chinese carps, the Indian carp, catla, tilapia and others, have been imported and the culture of indigenous fishes, such as milkfish, has been started.

Indonesia is one of the countries in the region in which fish culture has been developed to a great extent. The culture of milkfish might have originated in Java during the 15th century A.D. In the Javanese law code, "Kutara Menawa", believed to have been written in about 1400 A.D., punitive measures were laid down against those who stole fish from ponds. It is possible that the industry originated under the influence of the Hindu rule and the first 'Tambaks' were built by convicts who were sent to the coastal areas to work in the salt marshes and to guard the coastal fires. During the regime of the East India Company and the English occupation the ponds were considered to be government property and were leased out to the people. By about 1860 the ponds were given over to the people but special supervisors known as "Mantri Tambaks" were entrusted with the responsibility of their proper maintenance. In 1863 the acreage of tambaks was estimated to be about 80,000 of which more than 50 per cent may have been constructed before 1820. The development of existing coastal pond sites was completed by about 1900 and further ponds were mostly made on other tidal flats. During the regime of the Dutch, a considerable amount of research and extension work was done and this contributed greatly to the improvement of the industry in the country. The discovery of the African cichlid fish, Tilapia mossambica, in Java in 1939 by a fishery supervisor named Pak Mudjair was a landmark in the development of fish culture in the Indo-Pacific Region. During the Japanese occupation, when facilities for intensive milkfish culture declined, tilapia culture in fresh and brackish waters gained considerable popularity. By the time normal conditions were restored, their culture had become so extensive that the formulation of control measures was out of the question. Tilapia began to be cultivated in every available piece of water including ditches and pits, where the milkfish could not be grown. Many neighbouring countries in need of a hardy and prolific fish are now importing tilapia from Java and other areas. The gourami (Osphronemus goramy), the culture of which has been developed to a high level in Java, has been exported to several countries in the region, such as India, the Philippines and Ceylon.

The Philippine system of brackish water fish culture appears to have been derived from the Javanese. According to pre-war estimates, around the Manila Bay area alone there was an investment of 50 million pesos. After World War II this investment increased five to ten times and according to the latest estimates there is an annual investment of 250 million pesos in the Philippine pond fish industry, about 85,000 hectares of developed fish ponds producing nearly 23 million kg of fish valued at about 34 million pesos. In the absence of a suitable freshwater fish, the gourami was imported and, later on, the sepat siam (Trichogaster pectoralis) from Java. Considerable research on fish culture, especially of the milkfish, has been conducted in the Philippines with the help and collaboration of the United States Fish and Wildlife Service. In recent years several other freshwater fishes have been imported into the islands.

Japan has only very restricted inland areas for fish cultivation, but the Japanese have developed methods of intensive culture of several indigenous and exotic fishes. The culture of the land-locked salmon and trouts in ponds and streams has been possible due to the prevailing cold climate. Extensive development of fish culture in rice fields has been accomplished in recent years. The intensive culture of eels, "Ayu", etc., has also been developed and phenomenal yields are being obtained. However, the methods of culture adopted in Japan are not easily followed in most other countries of the region because the food materials supplied to the fish are expensive and, if these methods are followed in other countries, the price of fish may increase beyond the reach of the common man.

Fish culture for food production has not been attempted in any large way in the other countries of the region such as Australia, New Zealand and Burma. But in the first two countries mentioned the culture of cold water sport fishes has been developed and the construction of multipurpose fish ponds on agricultural farms is being encouraged.

The above brief review of fish culture development in the Indo-Pacific would show the great antiquity of the industry in the region. Although practised more as a skilled art, considerable experience and traditional knowledge has gone into the evolution of the technique. However, a proper extension of the practices has been greatly hampered for lack of sufficient knowledge of the basic scientific principles involved. This was fully realized after the last world war when the need for tapping every available source of food production became essential. Since then, national and international agencies are trying by all possible means to improve, perfect and extend the culture of warm-water fishes. Many countries, both within the area and outside, where the industry was never known, have become interested in it and are trying to increase food production by fish culture. To make the necessary technical guidance for fish culture available, agencies like the Food and Agriculture Organization of the United Nations have been organizing training centers and other means for disseminating scientific knowledge on the subject to fishery extension services. If the present tempo of development in research and extension continues, it can justifiably be hoped that the industry will advance very far during the coming years.

Nutrient Cycle in Ponds

Although, as a group, fishes are more economical to raise than higher animals, the relative efficiency of the cultivated species differs in the conversion of the various forms of organic matter into fish flesh. To assess this it is necessary to know the basic nutrient cycle and the food chains in aquatic environments. Mineral nutrients, air and energy in the form of sunlight and heat, are the basic components from which the original producers, the plants, build up organic matter. Decomposing organic matter forms the first link in the food chain and this is brought about by the bacterial flora in the water. Reducing bacteria are able to consume oxygen from the water and give off carbon dioxide. But as they do not have chlorophyll in their tissues, they are not able to

absorb carbon dioxide from the air. They obtain this from the decomposing organic products, such as sugar, starch and cellulose. The essential process of decomposition of dead plants and animals is often enhanced by the active ferments produced by some of the bacteria. Certain bacteria are able to break up proteins into ammonia and ammoniacal compounds. The nitrifying bacteria convert these compounds into nitrates which can be directly utilized by plants. By these processes the nitrogen reserves of the deal animals and plants are brought into the nutrient cycle. Nitrates and other nutrients, such as phosphates, may also be brought into a natural water area by drainage from the catchment area. Algae which can assimilate these nutrients directly flourish on them and they, in turn, form the food of either protozoans and rotifers or micro-crustaceans. The protozoans and rotifers also form the food of crustaceans or insects. These zooplanktonic organisms, with the algae (phytoplankton), generally form the food of smaller fish which are, in turn, fed upon by larger fish. When the algae, animal plankton, insects or the fish themselves die, bacteria act upon the dead tissues and the nutrient cycle is repeated. The above is only the bare outline of the nutrient cycle, and, actually in a pond, several other links may exist because the chain and biotic interaction may be more complex. However, a remarkable fact in this cycle is that the whole process is one of diminishing returns. There is continuous dissipation of energy, and thereby weight, all along the chain in the progress from the plant to the animal end. It is difficult to assess with any degree of accuracy the decrease in weight along the food chain from plants to animals. According to Birge and Judey (1922), the material which can be used as food by the plankton rotifers and crustaceans of Lake Mendota weighs twelve to eighteen times as much as these species. In the opinion of MacGinitie (1935), 10, 000 pounds of algae make 1, 000 pounds of tiny crustaceans, 1, 000 pounds of tiny crustaceans make 100 pounds of small fish, 100 pounds of small fish make 10 pounds of large fish, which might go to make 1 pound of man.

Basic Considerations in the Selection of Species

Profitable fish culture aims at the production of the maximum quantity of edible fish flesh from a given quantity of organic matter. The species selected should have a rapid growth rate, and it should be able to use the natural food resources efficiently. The usefulness of shortening the food chain to achieve this purpose will be obvious. A fish which can convert decaying organic matter or the next link in the chain, namely, algae, directly into edible fish flesh, is, from the food utilization viewpoint, superior to others. This is the reason for the preference of the Indo-Pacific fish farmers for herbivorous and detritus-feeding fishes, because, being non-predaceous, they have the additional advantage of being tolerant of other species in a pond.

Another consideration is the need to utilize all the available food resources for the production of fish flesh. Pond fishes have distinctive feeding zones and food preferences, so it is not entirely profitable to base the cultural operations on a single species. Fish culturists in China and India have, as a result of practical experience, evolved certain "fish associations" or groups of species which, when present in a pond together, will use up all the food resources. These compatibles are discussed in detail in a later chapter.

Even though the culture of non-predaceous fishes is more economical, it may not be advisable to restrict cultivation to those species in all areas. Human preferences are important in this respect. Carnivorous fishes are said to have a better flavor than herbivores. Also, in some countries the addition of a certain proportion of carnivorous fishes helps to maintain an optimum population density and contribute to the production of an adequate quantity of food fishes of the desired size. An industry to be successful has to cater for the consumers' tastes and a disregard of this may result in failure. As an example, the milkfish (Chanos chanos) is a highly relished

fish in south-east Asian countries, but the people in Kenya have no liking for it and the Department of Fisheries could not find a market for the fish they raised in the Departmental farms. The mere fact that a particular fish is more economical to raise or that it is a favorite fish in a country should not be the sole criterion for starting culture in another country.

Indigenous fishes, which are naturally suited to the environmental conditions, may be uneconomical or unfit for cultivation in their home country, so when suitable species are not available, the introduction of exotic species can be considered. There is, however, some reluctance among hydrobiologists to do this because, remembering the rabbit in Australia and the carp in America, they fear that exotic fish may compete with the indigenous fauna to such an extent as to upset the ecological balance of the waters. Pond culture, as at present practised in tropical countries, is virtually an upsetting of nature's balance to produce the maximum quantity of marketable fish from a water area. If an exotic fish can achieve this, from the point of view of fish culture economics, there is no reason why it should not be imported, but there is one contingency that must be considered, and that is the possibility of the fish escaping from the ponds into other waters where they might become a nuisance if not a pest. It is, therefore, essential that before cultivation of a foreign species is undertaken the necessity for the introduction is clearly established and controlled experiments have been conducted to assess their influence on the local fauna.

In some localities, especially in coastal areas, where the indigenous fish fauna is limited and stocking of indigenous freshwater forms is expensive, it is often possible to transplant euryhaline species into fresh waters. In some cases the fry can be directly transferred; in others they can be "acclimatized" by slow diminution of the salinity of the water. In practice, stocking with acclimatized fishes will be profitable only where suitable euryhaline species are available in the vicinity. Some euryhaline fishes grow at a more rapid rate in fresh rather than in brackish waters.

There is no "universal pond fish" that can be recommended for cultivation. The efficiency of fish production varies with species and environmental factors. Each species has its own preferences as to the organic matter it uses as food, besides the oxygen content, the temperature and the acid-alkaline range of the water it can inhabit. A particular species, though fast-growing, may be wasteful of food. On the contrary, a slow-growing species may be able to convert a given quantity of food into a greater weight of fish flesh than other species. Further, a fish's food may be such that it cannot be provided economically. One fish may not withstand adverse conditions or its flesh may deteriorate too rapidly to permit easy marketing, even though it may be highly relished. Similarly, a fish of indifferent flavor may have maximum sales appeal on account of its ability to remain alive out of water for considerable periods, and others may be suitable for salting. Extensive research and experimentation are essential to determine the species of fish most suited for each type of pond and the kind of food on which it grows best; economic investigations are required to decide which species can be raised most profitably. Accurate information on these aspects of tropical and subtropical pond fishes is extremely limited and what is known is mostly empirical.

THE CULTIVATED SPECIES OF THE REGION

The list below does not necessarily include all the fishes that are raised in ponds, but only those which, at the time of writing, are usually cultivated or are fairly well known in the region.

The scientific, common and local names in various countries and districts are given.

Pond fish culture is always changing and improving, so it is probable that some of the species have now been distributed to countries other than those indicated.

No attempt is made to describe the species with scientific accuracy: the descriptions are designed to enable educated fish farmers to identify particular fish.

Plankton and Detritus Feeders

Catla. Catla catla (Hamilton Buchanan)

India: Catla, Chepti, Boassa, Thoppa meenu, Yernaneri kendai, Botchee, Bakura, Bau, Dhekera, Thail, Theila, Tambra, Tay lee

Burma: Nga thaing

Distribution: West Pakistan, Punjab, North India, East Pakistan, Burma
Transplanted to South India and Ceylon

Body oblong, moderately compressed, head broad, eyes situated in lower half. Lower lip rather thick with continuous transverse fold. No barbels. Original dorsal fin in advance of pelvic fins. Large regular scales. Scales of lateral line 40 to 43. Body greyish in color on the back, silvery on the sides and beneath; fins darkish, sometimes nearly black. Maximum length about 1,800 mm.

Freshwater river fish, able to live in slightly brackish water; suitable for cultivation in confined waters. Does not breed in ponds, spawns occasionally under controlled conditions in special reservoirs (bunds). Reaches sexual maturity when about 56 cm in length. Spawning period in Upper India from June to September, in South India twice a year during monsoons. Eggs deposited in inundated shallow marginal areas of rivers. Eggs are transparent, spherical, 2.0 to 2.2 mm in diameter, increasing to 4.4 to 5.2 mm when swollen up.. Embryos hatch out 16 to 18 hours after fertilization. Adult characters attained after about six weeks. Larvae and fry collected from rivers, shipped over long distances and used for stocking ponds and tanks.

Larvae and young fry feed on unicellular algae. Fry longer than 2 cm feed chiefly on zooplankton organisms, preferably on Protozoa and Crustacea. Adults feed on decayed macrovegetation, Myxophyceae, Chlorophyceae, Bacillariophyceae, Protozoa, Rotifera, Crustacea and Mollusca. Surface and column feeder. Attains a length of 38 to 45 cm at the end of the first year, average weight 900 g. At the end of the second year the weight is 4 to 5 kg. Increase in length under favorable conditions 7.5 to 10 cm per month. Annual production in fertile ponds 1,100 to 2,200 kg total yield per hectare. Widely reared in India in ponds and tanks in association with other carps.

Silver Carp. Hypophthalmichthys molitrix (Cuvier and Valenciennes)

China: Lin yi, Leng yu, Paak lin, Pin yu, Tsue yu, P'ang t'ou yu
Malaya: Pey lin
Japan: Hakuron

Distribution: South and Central China (Yang-tze, West River, Kwangsi, Kwangtung).
Transplanted to Japan, Formosa, Thailand and Malaya, and from Malaya into Ceylon.

Body oblong, slightly compressed, height of body 3.5 times in total length. Head pointed, its length 3.3 in standard length. Snout bluntly rounded, lower jaw slightly protruding. Small eyes, diameter six times in length of head. Very small scales, lateral line scales 108 to 120. Abdominal keel from anus to thorax. Origin of dorsal fin behind ventrals, midway between tip of snout and base of caudal. Maximum length about 600 mm.

Freshwater river fish, able to live in slightly brackish water. Suitable for cultivation in confined waters. Does not breed in ponds; fry collected from rivers and reared in nurseries, later shipped over great distances. Spawns in the Yang-tze and its tributaries and in the West River in April, May, June, probably also in some rivers in Japan.

Larval stages feed on unicellular algae. Fry and adult fish feed on Flagellata, Dinoflagellata, Myxophyceae, Bacillariophyceae, Protozoa and Rotifera supplemented by decayed macro-vegetation and detritus. When kept in ponds it feeds well on artificial foods, such as bean meal, rice bran and flour. Highly valued pond fish. During first year usually kept stunted in nurseries. Average length at the end of the second year 30 cm, weight 900 g; length after third year 45 cm, weight 1.8 kg. Annual production of manured ponds up to 1,000 kg per hectare. Often reared in association with other species.

Big head. Aristichthys nobilis (Richardson)

China: Shong yu, Yung yu, Taai t'au yu, Haak kin yu, Fa lin yu
Malaya: Twa t'au
Japan: Kakuren

Distribution: South and Central China (Yang-tze, West River, Kwangsi, Kwangtung).
Transplanted to North China, Japan, Formosa, Vietnam, Thailand and Malaya, and from Malaya to Ceylon.

Body moderately compressed, depth of body 3.5 times in standard length. Head relatively large, length of head 2.8 times in standard length. Mouth oblique with lower jaw protruding. Snout somewhat depressed. Origin of dorsal fin behind ventrals and somewhat nearer to base of caudal than to tip of snout. Abdominal keel prominent behind ventrals scarcely extending to thorax. Lateral line scales about 100. Body dusky green on the back and the sides, pale beneath.

Freshwater river fish, suitable for culture in ponds in moderate and tropical climates. Does not breed in confined waters. Spawns from April to June in rivers in South and Central China. Fry collected from rivers and reared in nurseries, later shipped over long distances.

Larval stages feed on unicellular planktonic organisms. Fry and adults feed on all types of plankton. Bulk of food consists of Myxophyceae, Flagellata, Dinoflagellata, Bacillariophyceae, and the zoo-spores of Conjugales and Chlorophyceae. If zooplankton is available, it is readily taken along with phytoplankton. Rapid growing fish. In ponds average length at the end of second year 30 cm, weight 900 g, third year length 45 cm, weight 1.8 kg. Grows in ponds to 5 to 7 kg in weight. Annual production of manured ponds up to 1,000 kg per hectare.

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Sepat siam. Trichogaster pectoralis (Regan)

Thailand: Pla salid, pla bai mai
Indonesia: Sepat siam, Sepat siem, Siem
Malaya: Sepat siam
Vietnam: Ca sat rang
Cambodia: Trey kanthor

Distribution: Thailand, Cambodia, Vietnam.
Transplanted to Malaya, Indonesia, East Pakistan, Ceylon.

Body oblong, compressed, depth of body 2.2 to 3 times in standard length. Dorsal fin with 7 spines and 10 to 11 rays, anal with 9 to 11 spines and 36 to 38 rays. Pectoral fins longer than head. Mouth protractile, very small. First ray of ventral fin transformed into a long simple filament. Lateral line scales 42 to 47. Body dark-green on the back, lighter on the sides. Cross bands on head and body, interrupted lateral band from eye to caudal. Maximum length about 250 mm.

Freshwater river and swamp fish, suitable for cultivation in confined waters. Breeds and grows rapidly in rice fields. Spawns in ponds when appropriate measures are taken.

Reaches maturity when about 7 months old. Male fish prepares a bubble nest, about 5 cm in diameter, in which the eggs are deposited. A breeder contains 7,000 to 8,000 eggs, but a nest seldom yields more than 4,000 larvae. Eggs, containing an oil globule, are spherical, buoyant and yellowish in color. Embryos hatch out 36 to 48 hours after fertilization, yolk sacs absorbed within 3 to 7 days. Natural spawning season in Thailand April to October. In ponds no specific breeding season.

Larval stages and young fry feed on planktonic organisms. Adults feed on phytoplankton (Bacillariophyceae, Cyanophyceae, Flagellata), zooplankton (Ciliata, Rotifera, Cladocera, Copepoda), decayed Chlorophyceae and higher plants, and on detritus. In ponds, fish can be fed on aquatic plants (Ipomoea, Lemna).

In ponds and rice fields grows to length of 7 to 9 cm in three months, to 10 to 12 cm in 6 months, and to 16 to 18 cm in 12 months. Weight of full-grown fish 130 to 140 g. Suitable for cultivation in ponds up to an altitude of 800 m, most suitable water temperatures between 25° and 35° C. Annual production in manured ponds 250 to 350 kg per hectare.

*** See Kissing Gourami page 47.

Sepat djawa. Spotted gourami. Trichogaster trichopterus (Pallas)

Indonesia: Sepat, Sepat djawa, Seput idju, Sape, Sapat, Tuwakan
Thailand: Pla kadi, Pla kadi mor, Pla salark, Pla salarin
Vietnam: Ca sat buom
Malaya: Sepat ronggeng
Cambodia: Trey kamphlienh samre

Distribution: Indonesia, Malaya, Thailand, Cambodia, Vietnam

Body oblong, strongly compressed. Mouth somewhat protractile, very small. Origin of short dorsal fin above soft part of anal. Ventrals very small, first ray reduced into a long simple filament. Color of body very variable. Dorsal region olivaceous, greenish or greyish, lighter on flanks and below. Upper half of body with 15 to 20 irregular, partly confluent crossbands which may be broken up into spots. A distinct large black spot on the middle of the side and another at the base of the caudal. Maximum length 120 mm.

A freshwater river and swamp fish, partial to weed-crowded waters. Able to stand slightly brackish water. Breeds in confined waters including rice fields. Reaches sexual maturity when about 3 months old at a length of 8 cm. Male fish builds a floating nest from pieces of plants joined together with foam bubbles. Eggs white, 0.8 mm in diameter, pelagic, floating in the nest. Spawns every month. Embryos hatch out within 24 hours.

Larvae food consists of phytoplankton and detritus. Fry and adults feed on phyto- and zooplankton, epiphytic micro-organisms and decayed algae and higher plants.

Almost never reared in ponds as sole stock but often tolerated as desirable coarse fish. Breeds in weedy ponds without particular measures. Important as food fish in rice areas where considerable crops can be obtained by stocking fields with breeders, kept during the dry season in storage ponds of canals. Always occurs in association with other species in fields.

Fringe-lipped carp. Labeo fimbriatus (Bloch)

India: Sel kendai, Kammenu, Thama, Gandu meenu, Bahrum, Puddusi

Distribution: West Pakistan, Upper India, Madras, Orissa.

Dorsal profile of body more convex than abdominal. Width of head equal to length without snout. Snout obtuse, rather swollen and studded with pores, overhanging the mouth. Lips thick with fringed inner fold above and below. Short rostral and maxillary barbels. Pectoral fins nearly as long as head, not reaching the ventrals. Lateral line scales 44 to 47. Body silvery on the back, lighter on the sides and beneath. Fins marked with black, red spots on the scales. Dark blotch at the base of caudal in young specimens, sometimes also in adults. Maximum length about 900 mm.

Freshwater river fish, suitable for cultivation in confined waters. Does not breed in ponds. Fingerlings can be transported over long distances. Breeds in rivers during rainy season. Attains in ponds a length of 23 cm at the end of the first year and 31 cm at the end of the second year. Feeds during fry stage mainly on Bacillariophyceae and Desmidiaceae. Adult fish take filamentous algae together with Protozoa, Rotifera and Copepoda. Zooplanktonic organisms constitute about a quarter of the bulk of food. Average weight in ponds 450 g after 12 months.

Reba. Cirrhina reba (Hamilton Buchanan)

India: Rewah, Eelemose, Chittahri, Thari meenu, Chetchua porah, Chunchia pohada, Batta, Lasseem

West Pakistan: Soonee

Distribution: West Pakistan, India, East Pakistan.

Dorsal profile of body slightly more convex than abdominal. Width of head equal to length excluding snout. Snout slightly projecting, especially in young fish. Hexagonal scales. Lateral line scales 35 to 38. One pair of rostral barbels. Pectoral fins nearly as long as head. Caudal fin with deep, sharp lobes. Color of body silvery with bluish longitudinal bands above lateral line. Maximum size 300 mm.

Freshwater river fish, suitable for cultivation in confined waters. Does not breed in ponds. Used for pond culture only where fry of superior species are not available. Attains sexual maturity in the first year of life. Spawning period in India extends from June to September. Eggs are deposited in shallow water in river beds. Diameter of eggs 2.8 to 3.2 mm. Embryos hatch out after 15 hours; yolk sac absorbed after 3 days. Young fish have three caudal spots and dark lateral band extending from snout to base of caudal fin.

Up to a size of 2 cm fry feed on unicellular algae and Protozoa. In later stages an increasing proportion of animal food is taken. Fish more than 8 cm in length take the same food as adults. 70 to 80 per cent of the food consists of blue-green and green algae, diatoms and remnants of higher plants; rest consists of zooplanktonic organisms like daphnids, rotifers and insect larvae. Growth fairly rapid; length of 25 to 28 cm attained at the end of the first year.

White carp. Cirrhina cirrhosa (Bloch)

India: Ven kendai, Arugu

Distribution: South India

Dorsal profile of body more convex than abdominal. Width of head equal to length excluding snout. Four barbels, rostral pair rather long. Origin of dorsal fin in advance of ventrals. Lateral line scales 42 to 44. Color of body silver. Scales have red center except along abdomen where they are marked with grey.

Freshwater river fish, suitable for cultivation in confined waters. Does not breed in ponds. Attains sexual maturity in the first year of life at a length of 20 to 25 cm. Spawns in river sections with a rapid flow of water. Spawning period from July to November. Maximum length over 350 mm.

Food, when more than 8 cm long, consists of about 80 per cent phytoplankton (Bacillariophyceae and Myxophyceae) and the rest zooplankton, mainly Crustacea. Hardy fish, attaining a length of 25 to 30 cm and a weight of 330 g in ponds in one year.

Cauvery carp. Labeo kontius (Jerdon)

India: Currumunee kendai, Curromoolee kendai, Moogi halale

Distribution: Cauvery River and Coleron River in South India

Profile of head above eyes rather concave; interorbital space nearly flat. Lips thick with distinct inner fold, lower lip fringed. Four short barbels. Snout overhanging mouth. Origin of dorsal fin midway between snout and end of anal. Lateral line scales 38 to 41. Body generally reddish in color, darkest along back. Scales may have a reddish center. Maximum length about 60 cm.

Freshwater river fish, suitable for cultivation in confined waters. Does not breed in ponds. Spawning period during monsoon rains from June to September. Eggs demersal, transparent, 3.5 to 4 mm in diameter, deposited in river sections with swift current. Embryos hatch out within 27 to 30 hours. Hardy fish that can be transported over long distances. In ponds attains a length of 23 to 30 cm at the end of the first year and a weight of about 350 g.

Major part of food of adult fish consists of algal filaments, diatoms and pieces of higher plants. Copepods, rotifers and remnants of insects and worms are taken as well.

Nagendram fish. Osteochilus thomassi (Day)

Distribution: South India

Body oblong, moderately compressed. Snout overhanging, with fringed upper lip. No barbels. Origin of dorsal fin nearer to snout than to base of caudal. Pectoral fins as long as head. Lateral line scales 34. Color of body dull silvery along the back, silvery along the sides, dull white on the belly. A black band along the dorsal fin, caudal fin with dark outer edge. Maximum length about 500 mm.

Freshwater river fish, suitable for cultivation in confined waters. Does not breed in ponds. Attains sexual maturity at about 23 cm in length, about one year old. Spawning period from May to June. Attains a length of 30 cm in ponds, and a weight of 300 to 400 g at the end of the first year. Food of adult fish consists of filamentous algae and diatoms. Fish browse on bottom and at margins of ponds.

Sandkhol carp. Thynnichtys sandkhol (Sykes)

Distribution: South India, Burma, Malaya

Body spindle-shaped, head compressed, abdomen rounded. Head short, upper lip absent, short labial fold on the side of the lower jaw. No barbels. Eye without adipose eyelids, situated in the middle of the depth of head. Origin of dorsal fin slightly in advance of ventrals, about midway between snout and base of caudal fin. Small scales, lateral line scales about 120. Color of body silvery, head purplish. Maximum length about 600 mm.

Freshwater river fish, suitable for cultivation in confined waters, does not breed in ponds. Attains sexual maturity in the first year of life, about 30 cm long. Spawning period during rainy season from June to September. Fast growing fish, attaining in ponds and reservoirs a length of 45 to 60 cm and a weight of 0.9 to 1.4 kg at the end of the first year. Fry and adults feed on planktonic organisms in a proportion of about 80 per cent of Myxophyceae, Chlorophyceae and Bacillariophyceae and 20 per cent of Protozoa, Rotifera and Crustacea.

Golden carp or English carp. Carassius carassius (Linnaeus)
Also known as: Wild goldfish, Crucian carp, Prussian carp, Gibel

Distribution: Temperate parts of Europe, from where introduced into Japan, India, North Borneo, China and Indonesia, partly as ornamental fish, partly a food fish.

Body oblong, rather deep; mouth terminal, without barbels. Last simple ray of dorsal and anal fin ossified and serrated behind. Teeth in throat arranged in series of four. Color of body green or bright golden on the back, lighter on the belly. Rather large scales. Maximum length about 450 mm.

Freshwater river fish, also thriving in ponds and lakes. Breeds in confined waters. In tropical climate attains sexual maturity in the first year of life when about 10 cm long. Adhesive eggs, 0.8 mm in diameter, attached to aquatic plants or artificial collectors. Eggs hatch within 4 days, later in temperate climates. Spawns in temperate climate at the end of spring, in the tropics throughout the year. Golden variety often confused with Carassius auratus.

Can cross with Cyprinus carpio; it is therefore necessary to avoid its introduction into ponds with this species.

Feeds on phyto- and zooplankton, worms, insects and filamentous algae. Attains a size of 20 to 25 cm at the end of the first year in ponds, but only 10 cm in temperate climates.

Mata mera (Red eye). Puntius orphoides (Cuvier and Valenciennes)

Indonesia: Mata mera, Wadonan, Ampa, Bragalan, Beureum panon, Beureum mata, Mera sotja, Pekisch, Brek, Lundjar, Mere setjo, Pirik.
Thailand: Pla Kam chan, Pla Labok, Pla pok, Pla sa pok, Pla pok som
Cambodia: Trey ampil tum.

Distribution: Indonesia, Malaya, Thailand, Cambodia.

Body oblong, compressed, dorsal profile from snout to dorsal fin arched. Snout obtuse, four barbels. Height 2.5 to 3 times in standard length. Fourth spine of dorsal fin strongly ossified with 30 serratures behind. Anal fin nearly truncate. Lateral line scales 31 to 34. Scales with radiating longitudinal lines, often with pearly tubercles. Color of body silvery, brownish near back. Caudal fin with a broad blackish marginal band above and below. Iris bright red, red areas on gill covers. Maximum size about 250 mm.

Freshwater river and lake fish, suitable for cultivation in confined waters. Breeds in ponds throughout the year if specific measures are taken.

Natural breeding season in Java from December to April during rainy season. In ponds attains maturity at a length of 13 to 15 cm, about 8 months old. Eggs adhesive, about 1 mm in diameter, attached to aquatic plants, stones or artificial collectors. Fry attain a length of 5 to 8 cm after 2 months and 12 to 18 cm after 5 months. Size at the end of the first year about 25 cm.

Fry feed on unicellular algae, young fish and adults feed on phyto- and zooplankton, epiphytic vegetation and to a significant degree also on soft bits and decayed parts of higher plants. Eagerly takes artificial foods such as rice, bran and crushed maize. Often reared in ponds in association with nilem and kissing gourami. Also used for stocking rice fields. Pond culture of this fish started only recently.

Tambra. *Labeobarbus tambroides* (Bleeker)

Indonesia: Garing, Sengkareng, Tambra, Gadji, Tamburi
Thailand: Pla wien, Pla yard

Distribution: Java, Sumatra, Borneo, Thailand

Body spindle-shaped, height 3 times in standard length. Snout prominent, upper jaw strongly protractile, lips broad, swollen, thick, with anterior lobe on upper and long free median lobe on lower lip. Four barbels. Dorsal concave with strong osseous third spine, anal fin truncate, not reaching the caudal. Body covered with large scales, lateral line scales 23 to 24. Body silvery, back and fins dark. Maximum length 700 mm.

Freshwater river fish, sometimes reared in ponds. Does not breed in confined waters. Fingerlings collected for stocking purposes. Breeds during rainy season, Thailand July to August, Java February to April. Ascends rivers to lay eggs at the mouth of small tributaries which the young subsequently ascend. Eggs 2 to 3 mm, reddish.

Food consists of phyto- and zooplankton, decayed higher plants and remnants of worms and insects.

Belinka. *Puntius belinka* (Bleeker)

Indonesia: Belinka, Kapiah, Kepiat

Distribution: Sumatra and Malaya

Body oblong, compressed. Dorsal profile strongly arched from snout to origin of dorsal fin. Head about 4.2 times in standard length. Mouth terminal, lips thin, four barbels. Dorsal emarginate, fourth spine rather strong, coarsely denticulated behind; last ray of dorsal prolonged. Lateral line scales 30. Body silver, back dark, darkish longitudinal lines. Caudal lobes with black band. Maximum length 235 mm.

Freshwater river fish, suitable for cultivation in ponds. Cultivation restricted to certain areas in Central Sumatra. Could possibly be bred in ponds, fry mostly collected from rivers.

Feeds on planktonic and epiphytic organisms and soft aquatic plants.

Lampai. Puntius schwanefeldi (Bleeker)

Indonesia: Lampai, Lampan, Kapiah, Kapiat, Tenadak mera, Kopiat, Sumpai, Susin, Lempen
Malaya: Lampan
Thailand: Pla Kahae, Pla pam
Vietnam: Ca he

Distribution: Indonesia, Malaya, Thailand, Cambodia, Vietnam.

Body oblong, compressed. Profile strongly arched from snout to origin of dorsal fin. Height 2.3 to 2.4 times in standard length. Snout bluntly rounded, upper jaw slightly prominent, thin lips, four barbels. Dorsal fin concave with strong third spine. Anal deeply concave, also with strong third spine. Lateral line scales 35 to 36. Color of body silvery or golden yellow, dorsal fin red, caudal fin orange or red with black band at each lobe. Anal and ventral fins reddish. Maximum length about 350 mm.

Freshwater river fish, suitable for cultivation in confined waters. Spawns sometimes in ponds without application of specific measures. Possibility of pond breeding not yet investigated. Fry often collected from rivers. Feeds on planktonic and epiphytic organisms and very probably also on fresh and decayed aquatic plants. Cultivation in ponds restricted to certain areas in Sumatra and Malaya.

Grey mullet. Jumping mullet. Mugil cephalus Linnaeus

India: Thirutha, Boi, Ainj
Ceylon: Is barri goeya, Kitheya, Thel godeya, Manalei
Malaya: Belanak
Indonesia: Belanak, Gereh, Gereta, Gerout
Hong Kong: Chi yu, Wo t'ou
Vietnam: Ca doi
Philippines: Aguas, Saranaa, Belanak, Lumilog, Banak, Aligasin, Guisaa, Pili
Japan: Bora, Ina, Ina mabora, Todo

Distribution: Red Sea, coastal waters of Pakistan, India, Ceylon, Vietnam, China, Japan, Philippines, Australia, and in many regions outside the Indo-Pacific.
Does not occur or is very rare in the waters around the Greater Sunda Islands.

Body oblong, moderately compressed; dorsal profile nearly horizontal, abdominal profile strongly curved. Height about 4.5 times in standard length. Snout pointed, but broadly rounded when seen from above. Gelatinous eyelids reaching the pupil. Free borders of both the lips proved with yellowish teeth-like fringes (ciliae). Origin of first dorsal fin about midway between tip of snout and base of caudal. No distinct lateral line; counted from middle of the gill opening to the small scales at base of caudal there are 37 to 40 scales. Color of body greyish above and silvery below with a dark line along each row of scales in the upper half of the body. Dark lines less conspicuous in lower half of body. Maximum length about 500 mm.

Marine fish, entering estuaries, backwaters, deltas, and rivers; suitable for cultivation in confined waters. Can be acclimatized to brackish and nearly fresh water. Does not breed in ponds or rivers. Believed to spawn in sea during winter. Fry abundant in many shore areas, lacking in others. Collection period for fry in India from December to March, in Hong Kong from February to April. 2.5 to 3.5 cm long fingerlings can be transported over long distances; acclimatizes easily to fresh water.

Fry feed on phyto- and zooplankton with diatoms and epiphytic Cyanophyceae as main components of the diet. Adults feed on algal vegetation, debris and detritus, for a great part collected in the benthic region of the water. When reared in ponds consumes considerable quantities of decayed plants.

Reared in brackish and freshwater ponds and reservoirs of India, in brackish and saltwater ponds in Hawaii in association with other marine species, and in association with cyprinoid fishes in brackish water ponds in Hong Kong. Sometimes used for supplemental stocking of milkfish ponds. Highly valued food fish.

Annual production 900 to 1,100 kg per hectare; if artificial foods are given the yield might be as much as 1,500 kg.

The average rate of growth is:

1st year	14 cm
2nd year	24 cm
3rd year	33 cm
4th year	39 cm

A 50-cm fish weighs about 1,300 g and would be about 6 to 7 years old.

Grey mullet. Mugil dussumieri Cuvier and Valenciennes

syn: Mugil parsia Hamilton Buchanan

India: Parsia, Chrayakendai, Madava kendai, Madavil, Malan, Kanambu, Parse, Tarul

Pakistan: Korul

Burma: Nga kam

Ceylon: Brodeya, Manalu

Indonesia: Belanak, Gereh, Bale belana

Distribution: Coastal waters of India, Pakistan, Ceylon, Burma, Malaya, Indonesia, Philippines, New Guinea, Australia.

Body oblong, moderately compressed. Dorsal profile straight, height 3.2 to 4.4 times in standard length. Snout depressed, its front border formed by upper lip which is conspicuously ciliated. Origin of first dorsal fin slightly nearer to base of caudal than to tip of snout or midway. Posterior part of gelatinous eyelid well developed, covering iris totally or nearly so. Lateral line scales 28 to 30. Color of body greenish on the back, creamy beneath; often three to six blackish longitudinal stripes corresponding to the rows of scales on the sides of the body. Maximum length 400 mm.

Marine fish entering estuarine waters, often ascending rivers and migrating into freshwater lakes and swamps. Suitable for cultivation in confined fresh and brackish waters. Does not breed in ponds, but specimens 10 to 15 cm in length are often found with roe in inland waters. Believed to spawn in sea, fry occurring in littoral waters in India and Indonesia from October to April. Fry and fingerlings collected from estuarine waters are often used to stock fresh and brackish water ponds. Fry entering ponds with tidal water results in natural stocking of salt and brackish water ponds.

Fry feed on phyto- and zooplankton occurring in the surface layers of estuarine waters. Adult fish are bottom feeders, subsisting on benthic algae, micro-fauna, more or less decayed vegetable matter and detritus. Valued food fish, attaining in brackish water ponds a length of 15 to 19 cm at the end of the first year. Maximum length in ponds about 25 cm. Mostly reared in association with other species.

Herbivores

Milkfish, Chanos chanos (Forskal)

India:	Tullu caudal, Palai meen, Pala kendai, Palmeen tullumendai, Palabonte, Tullu
Ceylon:	Palai meen, Wekka
Malaya:	Bandang, Jangas
Thailand:	Pla nuan chan
Vietnam:	Ca moi dung
Java, Sumatra:	Bandeng, Bandang, Banding
Philippines:	Bangos, Banglot, Banglus, Bangilis, Bagnos
Hawaii:	Awa awa
Formosa:	Sabahi, Sard Bark hee, Moa sard bark
Japan:	Sabahii
North Borneo:	Belanak sembawa
Celebes:	Bolu, baulu
Mexico:	Sabalo, Sabalete

Distribution: From the Red Sea eastward to the Paumotu Islands. From Southern Japan to South Australia. Along the Pacific coast of North America from San Francisco to the waters of Mexico.

Body oblong, moderately compressed. Height about 4 times in standard length. Mouth terminal. Small scales, 75 to 80 along the lateral line. Scales forming a sheet along base of dorsal and anal fin. Axillary scales above and below pectorals and ventrals. Body silvery green above, bright silvery along the sides, whitish on the abdomen. Dorsal and caudal fin, tip of anal and inside of pectorals pigmented. Maximum length over 1,500 mm.

Marine and estuarine fish, suitable for cultivation in fresh and brackish water ponds. Does not reach maturity or breed in confined waters. Spawns in sea near the coast. Eggs pelagic, 12 mm in diameter, embryos hatch out within 24 hours. Larvae 12 to 15 mm, occur periodically in great quantities along sandy coasts and in estuaries. Periods of occurrence in various countries:

Ceylon:	March to April	and from	October to December
India:	March to August	and from	October to December
Indonesia:	March to May	and from	September to December
Thailand:	April to October		
Vietnam:	May to November		
Philippines:	April to June		
Formosa:	April to August		

Advanced fry (fingerlings) occur in quantities in estuarine waters of South India, Ceylon, Thailand and to a minor extent in some parts of Indonesia. Adult specimens are comparatively scarce in coastal waters; they are numerous in Ceylon waters.

Fry and fingerlings are used to stock ponds and reservoirs. In fertile waters fry reach a length of 50 to 70 mm at the end of the first month and 120 to 150 mm at the end of the second. The fish population of a pond might reach an average length of 40 cm and an average weight of 450 g within one year.

In sea and in open estuarine waters fry and fingerlings feed on Bacillariophyceae, Myxophyceae and remnants of Chlorophyceae; adult fish take diatoms, copepods, larval bivalves, fish eggs, etc. In brackish water ponds, fry mainly feed on the gree bottom growth of fertile ponds. This substance represents a biological complex consisting of more or less decayed green and blue-green algae, diatoms, protozoa, bacteria and detritus, and is known as "tai air" in Indonesia and as "lab lab" in the Philippines. It is readily eaten by Chanos during the entire period of cultivation. In ponds with luxurious growth of Chlorophyceae and Characeae Chanos also feeds on algal matter softened by decay. The relative proportion of decayed, decaying and fresh green algae eaten by the fish increases with its growth. Fish more than 450 g in weight take a comparatively large portion of fresh filamentous algae and parts of higher plants if the soft food stuffs, which they prefer, are not available in abundance.

In freshwater ponds and tanks Chanos feeds on vegetable planktonic and epiphytic organisms and on decayed macro-vegetation. Growth can be very rapid; lengths of 60 to 65 cm at the end of the first year have been recorded.

In Indonesia the production of brackish water ponds is 225 to 425 kg of Chanos per hectare per annum with an additional yield of shrimps and coarse fish. The average production of the ponds in the Philippines is estimated to be about 350 kg per hectare per annum.

Tilapia. Tilapia mossambica Peters

Indonesia:	Ikan mudjair
North Borneo:	Ikan java
Thailand:	Pla mor ted

Distribution: Rivers on the east coast of Africa from Algoa Bay in South Africa to the Webi Shebeli River in Somaliland. Since 1939 cultivated in Java, from where transplanted to Sunda Islands, Malaya, the Philippines, Thailand, Ceylon, Pakistan and India.

Body compressed, oblong. Height 2 to 3 times in total length. Upper profile of head concave, snout rounded. Length of head 3 times in total length. Pectoral fins as long or little longer than head. Ventral fins reaching origin of anal. Small scales, two incomplete lateral lines Ll I: 18 - 21, Ll II: 10 - 15. Color of body grey olive, brownish or blackish depending on the environmental conditions. Ventral and pectoral fins blackish. Dorsal and caudal fins edged with yellow. On the upper part of body 9 to 11 rather vague horizontal bands. During breeding period females greyish with black spots, males strikingly black, lower parts of head and mouth whitish, pectoral, caudal and dorsal fins with distinct red edges. Maximum length about 400 mm.

River fish, also inhabiting estuarine areas. Suitable for cultivation in confined waters, ponds, reservoirs and rice fields. Spawns without particular measures in all types of waters. Attains sexual maturity at a length of 8 cm when about 3 months old. Breeds throughout the year at intervals of about two months, except in subtropical climates, where propagation is interrupted during cold season. Male fish digs a hole in the bottom of the ponds, about 35 cm in diameter and 6 cm deep. Female lays 75 to 250 eggs which are immediately taken up in the mouth. Fertilization takes place in the mouth of the female. Embryos hatch out within three to five days. Larvae are kept in mouth and young fry return into mouth in case of danger for a period of 10 to 15 days after spawning. Breeding is continued even when the salinity of water rises to more than 35 p.p.m. Eggs of fish reared in brackish water are whitish, in fresh water yellowish. Diameter of eggs about 0.7 mm. In tropical climates suitable for cultivation from sea level to an altitude of 1,000 m. Optimum water temperature from 25° to 30° C. Lower limit of mean water temperature about 14° C.

Fry feed exclusively on diatoms and other unicellular planktonic and epiphytic algae. Adult fish take mainly vegetable food, chiefly Chlorophyceae, Myxophyceae and Bacillariophyceae. When vegetable foods are scarce, worms, insects, crustaceans, fish larvae and detritus are eaten. Pond fish readily take artificial foods like rice bran, oil cakes, flour, chopped leaves and kitchen refuse. When vegetable food is available in abundance, this tilapia does not care for animal food.

Rapid growth under favorable ecological conditions. Individual fish might attain a weight of 850 g at the end of the first year; in brackish water ponds part of the stock might reach a weight of 450 g in eight months. However, a great portion of the yield of a pond usually consists of fish 85 to 140 g in weight, since frequent spawning keeps the average weight low. Natural production of fertile ponds about 500 kg increasing to 1,200 kg if manure is applied. Lower production in moderate climates.

Rohu, Labeo rohita (Hamilton Buchanan)

India: Rohu, Ruee, Ruhu, Rohee, Rohit, Rue, Tembada, Massa, Tapra, Dhambra, Dumbra
Burma: Nga myit chin, Nga myit tsap nee

Distribution: From West Pakistan across Upper India to Burma. In peninsula of India southwards to Madras. Transplanted into most parts of India and to the Andamans and Ceylon.

Body deep, dorsal profile more convex than abdominal. Snout obtuse and compressed, projecting beyond the jaws. Lips thick and fringed with a distinct inner fold. Generally only one pair of small maxillary barbels, sometimes a second, rostral pair. Origin of dorsal midway between snout and base of caudal. Lateral line scales 40 to 42. Maximum length about 900 mm.

Color of body bluish or brownish along the back, silvery on the sides and beneath. Usually a red mark on each scale.

A freshwater river fish, able to live in slightly brackish water. Suitable for cultivation in confined waters. Does not breed in ordinary ponds. Fry and fingerlings, collected in rivers, can be transported over long distances with little mortality. Eggs reddish. Spawning season extends in North India from June to September. Eggs are deposited in shallow, inundated marginal areas of rivers, occasionally under controlled conditions in confined waters (bunds). Fry recognizable by three small spots in caudal region which gradually merge into one. Fins marked with vermillion red.

Fry feed on unicellular algae and zooplanktonic organisms. Up to 25 cm in length, rohu takes increasing quantities of decayed vegetable matter, including higher plants, which might form more than half the bulk of its food. Column feeder.

Attains a length of 35 to 45 cm and a weight of about 675 g in one year. Quicker growth has been observed. Maximum size is reached in about 3 years. Production 1,100 to 2,000 kg per hectare per annum in fertile ponds when reared in association with other carps.

Gourami. Osphronemus goramy (Lacépède)

Indonesia:	Gurami, Gurameh, Kalau, Kalua, Kalui, Kala, Kalowo
Thailand:	Pla min, Pla raet
South India:	Sangara
North Borneo:	Ikan batu
Vietnam:	Ca tai tuong
Malaya:	Kalui
Cambodia:	Trey remeas

Distribution: Indonesia, Thailand, Malaya, Cambodia, Vietnam. Transplanted to India, Pakistan, Ceylon, Philippines and to many areas outside the Indo-Pacific Region.

Body strongly compressed, oblong and elevated. Mouth small, protractile, oblique. Origin of dorsal fin far behind pectorals and above or behind origin of anal. Pectorals with a spine and five rays, the first of which is transformed into an undivided, articulated filament. Scales large, lateral line scales 30 to 33. Color of body brownish, or greyish with a dark spot at the base of pectorals. Young specimens often show faint oblique bands. Maximum length about 650 mm.

Freshwater fish living in rivers, swamps and lakes, suitable for cultivation in confined waters. Breeds in ponds if sufficient material for nest building is present. Can live in slightly brackish water. In open waters breeds during the dry season, in confined waters throughout the year. Reaches sexual maturity during second or third year, depending on environmental conditions. Spawner and milter pair off and build a nest from pieces of grass and weeds, or if present, from palm fibers. Nests are about 30 to 38 cm with a circular mouth of about 10 cm, closed with a kind of door. Nests are hidden between aquatic plants or along weedy margins of ponds, about 30 cm below the water surface. Female lays 500 to 2,000 eggs which are fertilized in the nest. Eggs buoyant with oil globules; embryos hatch out in 30 to 36 hours. Larvae float belly-up or attach themselves to plants by means of cement glands on the head, begin to feed from the fifth day after hatching. Adult features reached in about 4 months.

Larvae feed on micro-organisms (Rotifera and Infusoria) which develop in the decaying nest. Fry have a preference for insect larvae, crustaceans and coarse zooplankton, but also take pieces of soft vegetable matter. Adults feed mainly on plant leaves from embankments and pond margins.

Seeds of trees and shrubs are eagerly taken in open waters, in ponds, leaves of manihot, Colocasia, Carica or kitchen vegetables. In all stages, white ants, grasshoppers, frogs and worms might serve as occasional foods. Reared in ponds or small masonry cisterns completely dependent on artificial feeding. Resistant to low oxygen content due to accessory respiration by means of labyrinthiform organ. Under tropical conditions suitable for culture up to 800 m altitude. Growth best at water temperatures between 24° and 28° C. Lower limit for normal growth and reproduction, about 15° C.

Attains a length of 15 cm at the end of the first, 25 cm in the second and 30 cm in the third year. Wide variation in growth rate according to climatic and environmental conditions. Often reared in association with other species. Production of 200 kg per hectare per annum obtained by rearing alone in ponds.

Pearl spot. Etroplus suratensis (Bloch)

India: Karimoen, Tallathi, Krumpad, Karassa, Pallinchan, Seetha kendai, Cashimara, Pitul, Gundhala, Koonadala

Ceylon: Koraliya, Seththel

Distribution: India, Pakistan and Ceylon.

Body oblong, compressed, height of body $2\frac{1}{4}$ times length of head, 4 times in total length. Caudal fin slightly emarginate.

Color of body light green, eight transverse bands on the body, the first over the posterior part of the head, the last across the base of caudal fin. Most of the scales above the lateral line have a white pearly spot, irregular black spots on the abdomen. Specimens from salt water are deep purple in color with the bands almost black. Maximum length about 300 mm.

Brackish water fish occurring in estuaries, coastal lakes and creeks up to the tidal limits. Suitable for cultivation in confined, fresh and brackish waters. Breeds in ponds without particular measures. Believed to breed in brackish water throughout the year, in fresh water during the dry season. Sexual maturity reached during second year, when 15 to 18 cm long. Fish separate into pairs and clean a spot on the underside of submerged objects for the attachment of eggs. Stones wood, plants with a rough surface submerged to a depth of about 1 m are preferred. If there is insufficient space below the object, a cup-like excavation is made in the soil. The female lies flat in the nest and attaches the eggs one by one in layers to the object. The eggs are then fertilized. Figures varying from 1,300 to 6,000 are mentioned as total number of eggs contained in a nest. Eggs are oblong in shape, 1 to 2 mm in diameter, yellowish when just laid and brownish later. Embryos hatch out in 82 to 100 hours, larvae are about 5 mm long. On the fourth day after spawning the male prepares some shallow pits in the vicinity of the nest to which the newly hatched larvae are transferred. They are moved from one pit to another about once a day. After seven days the yolk sac is absorbed, and the fry then move in the vicinity of the pit, guarded by the mother fish. Adult characters are attained within a month after hatching, when about 18 mm long.

There is a difference of opinion about the food of larvae and fry. There are statements that minute animal life is the main food and vegetable food is taken only in the late larval stage. According to others the young fish are exclusively herbivorous and only the older fish feed on fish larvae and aquatic insects. Adults are mainly herbivorous feeding on blue-green and green algae (Oedogonium, Spirogyra, Oscillatoria, Lyngbya, Cladophora and Volvocales) and also on decaying plant remnants. They also feed on tender leaves of water weeds like Hydrilla and Vallisneria. Besides vegetable matter, pearl spot also takes zooplanktonic organisms, such as copepods, tadpoles, crustaceans, insects and worms. When reared in tanks they will eat eggs laid by other Etroplus.

Cultivated in ponds, tanks and reservoirs in the brackish water zone fairly extensively transplanted into fresh waters in inland areas of India. Must be 'acclimatised' to fresh water. In ponds attains a length of 10 to 12 at the end of the first year. Growth up to 30 cm has been observed in freshwater ponds. Seldom reared alone in ponds.

Milem. Osteochilus hasselti (Cuvier and Valenciennes)

Indonesia: Milem, Mellem, Melem, Monno, Monno. Wader Lenar, Meramas, Nangut, Palau, Palong, Pawas, Pawas kerbau, Paweh, Paweh gadan.
Thailand: Pla soi khao, Nok khao, Pla khi khom, Pla tu bo
Vietnam: Ca me, Ca lui
Cambodia: Trey kroum

Distribution: Indonesia, Malaya, Thailand, Vietnam and Cambodia.

Body oblong, compressed; height 2.5 to 3 times in standard length. Snout rounded, blunt with ventral lobe in which protractile mouth is hidden. Lips fringed. Two pairs of barbels. Origin of dorsal opposite eighth to tenth scale of lateral line. Lateral line scales 30 to 34. Caudal deeply emarginate with pointed lobes. Body tawnish brown or greenish brown on the back, lighter beneath; specimens from clear waters often green with creamy sides and white belly. Six to eight longitudinal lines of black spots following the rows of scales with a spot on each scale. Caudal, anal and ventral fins reddish. A round black, often very faint, spot on the base of the caudal fin. Maximum length 350 mm.

Freshwater fish living in rivers and lakes, suitable for cultivation in confined waters. Breeds in ponds if appropriate measures are taken. In open waters breeds at the end of the rainy season. In ponds throughout the year, if there is running water. Reaches sexual maturity at the end of the first year, 15 to 20 cm in length. Eggs transparent, semi-buoyant, about 2 mm in diameter when swollen. Eggs deposited in rivers on gravel banks in sections with moderate current, and in lakes and swamps where small streams debouch. Will spawn in ponds, if a strong flow of water across a bed of coarse gravel or stones can be produced suddenly. Special spawning ponds are required to produce the conditions for propagation.

Larvae and fry feed on phyto- and zooplankton, unicellular algae providing the bulk of food. Bacillariophyceae, Cyanophyceae, Desmidiaceae, and zoospores of Chlorophyceae together with Flagellata and Rotifera comprise the normal diet. Adults take Bacillariophyceae, Desmidiaceae, Chlorophyceae and soft or decayed leaves of higher plants. Typical feeder of 'couverture algologique' adhering to the leaves of aquatic plants and rasping off the covering growth of vegetable micro-organisms.

Widely used as pond fish in Java where it attains in ponds a length of 20 cm and a weight of 350 g at the end of the first year. In tropical climates suitable for cultivation up to an altitude of 800 m. Most suitable water temperatures from 18° to 28° C. Production in ponds about 300 kg per hectare per annum.

Tawes. Puntius javanicus (Bleeker)

Indonesia: Tawes, Bader, Putihan, Bader putihan, Tjibris, Djakare, Kabonganm, Badir, Kandia, Rampang
Thailand: Pla tapian khao
Vietnam: Ca tre vinh

Distribution: Indonesia, Thailand, Vietnam, transplanted into Ceylon.

Body strongly compressed, elevated dorsal profile arched, often concave. Height about 2.5 times in standard length. Snout pointed, mouth terminal, small, with two pairs of barbels. Barbels often very minute. Origin of dorsal opposite to tenth scale of lateral line. Dorsal fin emarginate, fourth spine very strong, dentated behind. Lateral line scales 29 to 31. Scales with numerous undulated longitudinal lines. Body silvery, darkish on the back, creamy white beneath. Base of scales grey to dark. Maximum length over 500 mm.

Freshwater river fish but thrives in brackish water up to salinity of 7°/oo. Suitable for cultivation in confined waters, fresh and brackish water ponds, reservoirs and to some extent also in rice fields. Breeds in ponds if appropriate measures are taken.

Spawns in rivers at the beginning of the rainy season. Eggs transparent, demersal, 1 mm in diameter swelling to 2 mm deposited on mud banks in rivers where tributaries join the main stream. In ponds attains sexual maturity within the first year when about 25 cm long. Spawns in ponds when suddenly transferred into fresh rainwater.

Larvae feed on unicellular algae and minute zooplankton. Fry and adult fish feed on aquatic vegetation (Chlorophyceae, Characeae, Ceratophyllaceae, Polygonaceae, Najadaceae) and in swamps also on grasses. Column and surface feeder, can keep irrigation reservoirs and water works gravel filters free from vegetation. In tropical climates suitable for cultivation from sea level up to an altitude of 800 m. Optimum temperatures from 25° to 33° C. Minimum temperature about 15° C. Often reared in brackish water ponds in association with milkfish. Attains in ponds a weight of 250 to 500 g at the end of the first year. Annual production of ponds up to 500 kg per hectare per annum. A second-rate table fish when fresh, very suitable for drying and salting.

Grey mullet. Mugil corsula Hamilton Buchanan

India: Corsula, Elanga, Arwari, In-gelee, Andwari, Hardwatre, Kakuda, Kekeranda, Halla, Hira, Khalla, Pangdara, Urul
Burma: Nga-sheng

Distribution: India, Pakistan, Burma

Body elongate, moderately compressed. Dorsal profile nearly straight, head depressed. Eyes protruding and elevated above the flat crown of the head, devoid of gelatinous eyelids. Upper lip thick, single row of cilia (teeth) on both jaws. Lateral line scales 48 to 52. Color of body dull brown above and lighter beneath. Dorsal and caudal fins marked with grey. Maximum length about 450 mm.

Considered to be a freshwater fish, occurring also in estuarine and coastal waters. Suitable for cultivation in confined waters. No definite information about breeding in ponds. Fry collected from rivers are used for stocking. Spawning season during the southwest monsoon. Eggs pelagic and semi-buoyant, about 1 mm in diameter. Contain an oil globule, more than half the diameter of the egg in size.

Fry in confined waters feed mainly on copepods and small insects. Adults feed on filamentous algae and the animal and vegetable organisms entangled in them. Often enter ponds, tanks and rice fields as extraneous fish. Said to grow to 35 to 45 cm in length in three years.

Grey mullet. Mugil tade Forskal

India: Bhangon
Indonesia: Belanak sipit, Gereh, Djumpul

Distribution: Red Sea, coastal waters of Pakistan, India, Ceylon, Burma, Malaya, Thailand, Vietnam, Philippines, Indonesia, Australia.

Body more or less spindle-shaped, dorsal profile horizontal, from crown of head to snout strongly sloping. Height 4.2 to 5.2 times in standard length. Gelatinous eyelids covering at least half of iris. Upper lip fleshy with minute cilia (teeth) in the upper jaw. Lateral line scales 33 to 35. Origin of dorsal nearer to end of snout than to base of caudal. Color of body greenish or olivaceous above, silvery beneath, five to seven indistinct longitudinal lines corresponding with the rows of scales. Maximum length about 700 mm.

Marine fish which easily adapts itself to estuarine and freshwater conditions. Suitable for cultivation in confined waters. Does not breed in ponds. Spawns in sea in India during the south-west monsoon, in Indonesia during the west monsoon. Specimens, 20 cm long often found with roe in ponds. Fry appear in estuarine areas, entering creeks, swamps and brackish water ponds.

Fry feed on phyto- and zooplanktonic organisms which they collect from the surface layers of the pond. Adults feed mainly on the unicellular and filamentous Myxophyceae, Bacillariophyceae and Chlorophyceae matted on the bottom of the pond. Unable to segregate components, they also consume the small animals living in the benthic layers and consequently take up detritus and soft vegetable matter.

Fry collected in shore areas are transplanted to fresh and brackish water ponds. Specimens 20 cm long with roe are often found in ponds. Entering fry often provides a substantial part of the crop of extraneous fish in brackish water ponds. Cultivated fish attain a length of 24 to 25 cm at the end of the first year, and of 34 to 36 cm at the end of the second. In freshwater ponds weights have been recorded of 1.4 to 1.8 kg at the end of the first year. Often cultivated in association with other species.

Ayu. Plecoglossus altivelis Temminck and Schlegel

Distribution: Southern Japan, Korea, northern part of Formosa.

Body slender, moderately compressed. Head blunt, typical comb-like teeth on maxillary. Small scales 149 to 169 along the lateral line. Color of body darkish green on the back, fading to

yellow on the sides, whitish on the belly. A yellowish blotch behind pectorals. Dorsal fin light yellow with dark anterior margin. Pectorals and ventrals light orange, caudal and anal yellow, adipose fin dark green with crimson upper edge. Maximum size about 250 mm.

Migrating form ("Ayu") ascends rivers during March to May when about 7 cm in size, stays in headwaters until August or September and then descends to lower reaches to spawn during October and November. Eggs adhesive, about 1 mm in diameter, deposited on gravel banks. Embryos hatch after 14 to 20 days at temperatures of 15° to 20° C. Fry migrate to sea.

Landlocked form ("Koayu"), inhabiting Lake Bima and several other inland waters, similar in character in character to migrating ayu, maximum length 10 cm, increasing in size if transplanted in rivers. Fry collected in lakes and rivers. Eggs obtained by stripping are artificially fertilized and shipped over great distances.

Fry and adult fish feed on algal vegetation (diatoms, blue-green algae, etc.) attached to pebbles and stones in river beds.

Omnivores

Common carp, European carp, German carp. Cyprinus carpio Linnaeus

China: Lei yu, Li yu
Japan: Koi
Indonesia: Green varieties: Tambra, Tombro
Orange-colored varieties: Ikan mas, Masmassan, Lauk mas, Emas, Rajo, Emeh.
Malaya: Lee Koh
Vietnam: Ca chep, Ca gay, Pa nay

Distribution: China, Japan, Vietnam, Thailand, Ceylon, India, Philippines, Australia, Malaya, Indonesia.
Autochthonous in China and Russia, transplanted in the Middle Ages to Europe and East-Asian countries. Wild or cultivated in all parts of the world.

Body oblong, moderately compressed. Protractile mouth with smooth simple lips. Three rows of teeth in throat. Two pairs of barbels, one pair sometimes rudimentary. Long dorsal fin with last simple ray ossified and serrated behind. Origin of dorsal fin opposite to that of ventral. Height of body, development of fins and scales, color of body and size subject to great variation.

There are several varieties and numerous sub-varieties of common carp in the Indo-Pacific Region. China has the "fat-bellied carp" of Kwantung and Kwangsi, and the green "long-bodied carp" of the Yang-tze Region. Indonesia has the orange-colored carp (Cyprinus carpio var, flavipinnis C.V.) which has split into many sub-varieties. Some of these are excellent pond fish, as for instance, the lemon-colored Sinjonja and the gold-brown Kantjera domas. A quick-growing green variety, the "Punten carp", with stabilized genetic characteristics, was developed in 1933. European varieties of carp are, or have been, cultivated in Ceylon, India, Pakistan, Indonesia and Japan. The imports have often been cross-bred with local varieties until the characteristics of the original stock practically disappeared. Mirror carp (C. c. var specularis) of the Galician variety

was introduced to Indonesia in 1927 and later also mirror carp of the Franconian variety. India and Ceylon have a stock of carp, imported in 1914 from Prussia. It is now split up into scales carp, leather carp (C. c. var. nudus) and mirror carp, all of which have lost the typical proportions of the German varieties. These have a relation of height to standard length of 1:2 to 2½ with varieties of Aischgrund (Germany) or Royale (France), while the carp reared in the Indo-Pacific regions have one of 1:2.7 to 3.3. In its original habitat common carp is a river fish showing little disposition to dominate the habitat. Domesticated for centuries, it is an extremely valuable fish for cultivation in freshwater ponds, reservoirs and rice fields; the "fat-bellied carp" is suitable for cultivation in brackish waters also. It is a hardy fish, resistant to low oxygen content and restricted space.

Spawning season in open waters is early spring, in tropical climates at the beginning of the rainy season, when river margins become flooded. Cultivated carp spawns in Canton in December, in Hong Kong in January, in the Yang-tze Region from April to June. In Japan the spawning season is from April to May. It spawns throughout the year in tropical climates with a peak period from January to April. It becomes mature when about 6 months old at a length of about 25 cm, later in moderate climates. In Europe carp spawn only in the third or fourth year, and only when the water temperature reaches 18° C. The eggs are creamy or yellow, 1.5 to 2 mm in diameter, adhesive. They are attached by the female fish on to aquatic plants or other objects in the pond at the rate of about 100,000 eggs per kg of female. Embryos hatch out within six days at a water temperature of 18° C, in three days at a temperature of 25° C and within two days at 30° C.

Young fry feed on Protozoa and small Crustacea. From about 10 cm in length the bulk of food consists of bottom-dwelling aquatic animals, such as Chironomidae, Ephermeridae, Trichoptera, Tubificidae, and Mollusca. They are eaten together with considerable quantities of more or less decayed vegetable matter and ephiphitic plankton. Carp collects food by taking bottom mud into the mouth, sifting out digestible particles and rejecting the rest. This habit destroys benthic vegetation and makes the water turbid. In searching for worms and insect larvae it burrows holes into the embankments.

Common carp can be cultivated under tropical conditions up to an altitude of 1,000 m above sea level. Below 150 and above 600 m growth is retarded. Optimal water temperatures between 20 and 25° C. Under favorable conditions the rate of growth is 2.5 to 5 cm per month. A weight of 1 kg at the end of the first year, and of 2 kg at the end of the second are within the average, but low stocking rates make higher weights possible. In Europe the average weights are: 50 to 100 g at end of first year; 500 to 1,500 at end of second year; 1,000 to 3,000 g at end of third year. Now, because of the ascites disease, the rearing is limited to two years. Annual production of ponds is 500 to 600 kg in India, 1,000 to 1,000 kg in Indonesia, 2,000 to 5,000 kg in Japan. In Japan, silk worm pupae are given as supplementary food; in Europe, maize, lupins or potatoes.

Grass carp.	Ctenopharyngodon idellus (Cuvier and Valenciennes)
China:	Wuan yu, Ts'ou yu, Ts' o yu, Waan yu
Hong Kong:	Waan yu
Vietnam:	Ca cham
Malaya:	Chow hu, Wan yu
Japan:	Sogyo
	Distribution: South Central and North China. Cultivated in Formosa, Thailand, Malaya and Japan. Transplanted into Ceylon from Malaya.

Body elongate, moderately compressed. Head broad with short round snout. Upper jaw slightly longer than the lower. No barbels. Double rows of compressed, comb-like teeth in throat. Origin of short dorsal fin slightly in advance or opposite to that of ventral. Scales of moderate size. Lateral line scales 42. Color of body dark grey above and silvery on the belly. Maximum length above 1,200 mm.

A freshwater river fish suitable for cultivation in fresh and slightly brackish water ponds. Does not breed in confined waters. Spawning season in China from May to June. Eggs deposited in the middle of the river in a strong current, hatching out in 30 to 40 hours at a temperature between 25° and 30° C. Larvae develop adult characters in 15 to 20 days after hatching.

Young fry feed on phyto- and zooplankton. When about 2.5 cm in size, fry begin to feed on aquatic vegetation, such as Lemna and Spirodella. At that size artificial food like rice bran, bean meal and dried cow dung is eagerly taken. Adult fish have a distinct preference for vegetable food, such as grass, leaves of trees, weeds and all kinds of water plants. Bran, oil cakes, silkworm pupae, kitchen refuse, night soil and dung are often given as supplementary food. A voracious fish, grass carp has been observed to eat decayed clothes and other such matter.

Length at the end of the first year 15 to 30 cm, weight 225 to 650 g. Second year: length 60 cm, weight 1.8 to 2.3 kg. After four years the weight may be more than 4.5 kg. In the Yang-tze and the West River Systems fish weighing 9 to 13 kg are common; fish of more than 20 kg have been caught.

Seldom reared alone in ponds. In association with other species production of a pond depends on the amount of food given, since natural food supply would become exhausted after a brief time.

Mud carp. Cirrhina molitorella (Cuvier and Valenciennes)

China: T'o ling yu, Ling yu
Formosa: (Taiwan): Kang hee
Malaya: Leng chee, Tho lang yu

Distribution: South and Central China (Kwangtung, Kwangsi and Fukien). Cultivated in Formosa, Thailand and Malaya.

Body oblong, compressed, snout blunt, sometimes tuberculated. Mouth inferior with a fold covering the fringed or striated upper lip. Lower lip provided with small roundish papillae. Both jaws covered with a soft and flexible leathery sheath. Height 2.8 to 3.5 times in standard length. Scales of moderate size, lateral line scales 37 to 41. Color of body silvery; crescent-shaped bluish bars with light spaces between. In young specimens a darkish spot at base of caudal. Maximum length about 350 mm.

Freshwater river fish, suitable for culture in confined waters. Does not breed in ponds. Fry shipped over long distances for cultivation in ponds. Spawning season in China from April to May.

Fry and adult fish feed in confined waters on the debris accumulating at the bottom whether it is of vegetable or animal origin. Dead matter is consumed with living micro-fauna and flora. Takes artificial food from the bottom of the pond. Length at the end of the first year 2.5 to 7.5 cm, weight 25 to 75 g (often kept stunted in nurseries). Length at the end of the second year 25 cm, weight 300 g, end of the third year length 30 cm, weight 600 g. Maximum weight about 900 g. Mostly cultivated in association with other species. Serves as scavenger; crowded into a pond, it does not compete with column and surface feeders.

Black carp. Mylopharyngodon piceus (Richardson)

China: Hak waan yu, Ts'ing yu, Ching yu
Malaya: Oh chow

Distribution: South and Central China (West River System and Yang-tze). Cultivated in Malaya, Vietnam, Thailand and Japan.

Body oblong, moderately compressed. Head slightly depressed, mouth small and oblique, with a single row of molar-like teeth. Abdominal profile rounded. Height 3.5 to 4 times in standard length. Origin of short dorsal above ventrals. Scales of moderate size, lateral line scales 40 to 43. Color of body brown, darker above than beneath. All the fins are black. Maximum length 1,800 mm.

A freshwater river and lake fish, suitable for cultivation in confined waters. Does not breed in ponds. Fry collected in rivers, after rearing in nurseries, shipped over long distances. Black carp feed on bottom-dwelling animals but have a preference for mulluscs which they are able to crush with their teeth. Pond fish are often fed with snails collected from streams and lakes. (Kiangsu and Chekiang). Length at the end of the first year 2.5 to 12.5 cm, often kept stunted in nurseries. Length at end of second year 30 to 40 cm, weight 2.5 kg, end of third year 65 cm, weight 3.5 to 5 kg. In lakes and rivers the fish attains a length of 1.5 to 1.8 m and a weight of more than 15 kg. Little esteemed as pond fish outside China, transplanted to Formosa and Malaya only as extraneous fish in shipments of other cultivated species from Japan.

Mylopharyngodon aethiops (Basilewsky)

Vietnam: Ca cham

Distribution: South China and Vietnam

Body elongate and compressed, abdominal profile rounded. Height 4 to 4.5 times in standard length. Mouth terminal lower jaw slightly shorter than upper jaw. Origin of dorsal nearer to base of caudal than to tip of snout. Lateral line scales about 45. Color of body greyish, fins prominently black. There is a possibility that the fish is identical with M. piceus.

A freshwater river and lake fish, suitable for cultivation in confined waters. Does not breed in ponds. Fry collected from rivers and lakes are reared in ponds in Vietnam in association with common carp, Hypophthalmichthys harmandi and Labeo collaris. Spawning season in the Red River area in June.

Mrigal. Cirrhina mrigala (Hamilton Buchanan)

India: Mrigala, Naini, Mirka, Mirga, Mirrgali, Mirkali, Mirrga, Mori, Morakha, Mor ah kee, Naraini.
Burma: Nga kyin, Nga gyein

Distribution: West Pakistan, Upper India, Deccan Assam, East Pakistan, Burma, Madras.

Body oblong, moderately compressed. Width of head equal to length behind the eyes, which are located in the anterior half of the head. One pair of barbels. Origin of dorsal nearer to snout than to base of caudal. Scales of moderate size, lateral line scales 40 to 45. Caudal fin deeply forked. Color of body silvery, dark grey along the back, sometimes coppery. Pectoral, ventral and anal fins tinged with black. Eyes golden.

Freshwater river fish, suitable for cultivation in confined waters. Does not breed in ponds, but sometimes in reservoirs (bunds) when specific measures are taken. Larvae and fry collected from rivers are able to stand transport over long distances. Attains sexual maturity when about one year old. Spawning period in Upper India from June to September. Eggs about 1.5 mm in diameter, swelling up to 3 to 4 mm. Embryos hatch out 16 to 19 hours after fertilization; yolk sacs prolonged posteriorly. Adult characters attained after about 24 days.

Fry up to a length of about 25 mm feed preferably on zooplankton, especially on Crustacea and Rotifera. Planktonic algae are taken only as emergency food. Adult fish subsist on blue-green and filamentous green algae, diatoms, and pieces of higher plants which make up together about 50 per cent of the bulk of food. Rest consists of decayed vegetable matter, mud and detritus. Flagellates, rotifers and small crustaceans are taken incidentally only. Bottom feeder, suited for cultivation in association with mid-water or surface feeders.

Cultivated in ponds, fish attain a weight of about 340 g and a length of 24 cm after 6 months, and a weight of 1.1 kg to 1.8 kg and a length of 45 to 61 cm at the end of the first year. Under very favorable conditions fish can reach a weight of 2.3 kg and a length of 66 cm within one year. Ponds containing sufficient quantities of decayed organic matter are able to produce more than 1,100 kg per hectare per annum.

Calbasu. Labeo calbasu (Hamilton Buchanan)

India: Dai, Kanoshi, Nallagandu meenu, Kemmachhalu, Kemmenu, Kala beinse, Kala basu, Kunda, Mahlee, Kaliaro, Kalag honi, Kalia, Kalyalora.
Pakistan: Baush, Kalibaush, Kalbons, Kalahan, Di, Di hee
Burma: Nga nek pya, Nga noo than, Ngt ong tong

Distribution: West Pakistan, Upper India, South India, East Bengal and Burma.

Body oblong, moderately compressed. Width of head equal to its length without snout. Mouth narrow, obtuse; lips thick and fringed, each with a distinct inner fold. Two pairs of barbels. Origin of dorsal fin midway between snout and base of caudal. Lateral line scales 40 to 44. Caudal deeply forked. Color of body slate black, scales sometimes with a scarlet center. Eyes red in color. Maximum length about 900 mm.

Freshwater river fish, suitable for cultivation in confined waters. Able to stand slightly brackish water. Does not breed in pons, occasionally in reservoirs (bunds) Fry collected from rivers and shipped over great distances. Spawns in India during the monsoon from May to July. Eggs deposited on flooded river margins, oval in shape, 5.3 to 6 mm in diameter, bluish in color, demersal, non-adhesive. Embryos hatch out 15 to 19 hours after fertilization, adult characters attained after about 30 days.

Young fry up to 2 cm in length feed on unicellular algae, thereafter food consists of about 30 per cent phytoplankton, about 50 per cent zooplankton (Rotifera and Crustacea) and the rest decayed organic matter and detritus. One investigator found the food of young fry mainly consisting of Crustacea, that of larger fry consisting of 75 per cent decayed vegetable matter. Adult fish feed on organic debris from the bottom of pond, together with benthic animals, plants and ephiphytic plankton.

Reared in ponds and reservoirs in India and Pakistan, often in association with other species. Attains a weight of 450 g and a length of 30 to 35 cm at the end of the first year.

Bata. Labeo bata (Hamilton Buchanan)

India: Dunguda porah, Dommarci batta, Gootellah, Bango, Tohirri

Distribution: India (Orissa, Bengal, Assam)

Body oblong, moderately compressed. Snout blunt, lips thin and continuous. Lower lip with shallow groove along hind edge. Lower jaw with a tubercle on the inner side. Upper edge of dorsal fin concave. Lateral line scales 37 to 40. Color of body silvery, darkish on the back, lower fins orange, all fins with fine black spots. Coloration varying with age.

Freshwater river fish, suitable for cultivation in confined waters. Does not breed in ponds. Fry collected from rivers, able to stand transport over long distances. Spawning season in India during monsoon from May to July. Believed to feed on phytoplankton, zooplankton and filamentous algae. Cultivated in ponds and tanks in India; no data available about rate of growth.

Copper mahseer. Barbus (Lissochilus) hexagonolepis Mc Cleiland

India: Boka, Bokar, Boolooah, Bhorkol, Buluk, Mirpunia, Kantase, Karambai
Nepal: Katli

Distribution: Upper India, Assam, Cauvery River in South India

Body oblong, compressed, snout obtusely rounded, prominent; mouth large, inferior. Two pairs of barbels. Origin of dorsal opposite or slightly in advance of ventrals; last undivided ray of dorsal osseous and entire, two spines in anal fin. Lateral line scales 28 to 31. Color of body deep bluish grey, darkish fins. Variation in color according to nature of waters. Maximum length aboe 900 mm.

Freshwater fish at home in hill streams, suitable for cultivation in confined waters. Breeds in ponds when running water with a temperature of about 20° C can be provided. Spawning ponds should have gravel bed. Mature fish can be stripped and eggs artificially fertilized. Spawning season from April to October with a peak season in August and September. Eggs spherical in shape, demersal. Embryos hatch out 4 to 7 days after fertilization. Female fish become mature at a length of about 20 cm, males at 9 cm. Young fry feed on diatoms and other planktonic algae (60 per cent) and on zooplankton (Protozoa, Rotifera, and Crustacea), about 40 per cent. Adult fish feed voraciously on aquatic weeds, insects and their larvae and molluscs. Esteemed game fish, reaching a weight of more than 10 kg.

Attains in ponds a length of 15 to 30 cm and a weight of about 110 g at the end of the first year.

Carnatic carp. Barbus carnaticus Jerdon

India: Poaree, Kendai, Saal kendai, Shellee, Gidpakke, Giddikaoli

Distribution: South India

Body oblong, moderately compressed. Snout short, obtuse, two pairs of short, thin barbels. Last of four undivided spines of dorsal fin is osseous and entire. Origin of dorsal in advance of ventrals and midway between snout and base of caudal. Lateral line scales 30 to 32. Color of body greenish brown, dull white, glossed with gold, on the sides and beneath. Maximum length more than 1, 000 mm.

Freshwater river fish, suitable for cultivation in confined waters. Does not breed in ponds. Spawning season during the monsoon months. Reaches sexual maturity when about 20 cm in length. Breeds in rivers from where fry collected for rearing in ponds. Young fry feed on phytoplankton (55 per cent), zooplankton (10 per cent) and aquatic insects (45 per cent). Higher plants, filamentous algae, also crustaceans, insects and fish remnants have been recorded as food components of adult fish.

Attains in ponds a length of 25 to 30 cm and a weight of about 115 g at the end of first year.

Hypophthalmichthys harmandi Sauvage

Vietnam: Ca duong, Ca coc

Distribution: Vietnam, Laos

Body oblong, height 3 times in standard length. Snout obtusely rounded, no barbels. Eyes situated very low on the sides of the head. Color of body silvery grey.

A freshwater river fish suitable for cultivation in confined waters. Does not breed in ponds; fry collected from rivers and reared in ponds, able to stand transport over long distances. Column feeder, mainly taking plankton and organic debris. Often reared in association with common carp, Labeo collaris, and Mylopharyngodon aethiops, providing the main part of stock.

Squaliobarbus curriculus (Richardson)

China: Ma lang yu
Vietnam: Ca chay, Ca roi, Ca thay

Distribution: South China, Vietnam, Laos

Body elongated, moderately compressed; height about 4.5 times in standard length. Snout conical, prominently, two pairs of small barbels. Origin of dorsal midway between tip of snout and base of caudal. Lateral line scales 40 to 48. Color of body silvery, fins darker.

Freshwater river fish, suitable for culture in confined waters. Does not breed in ponds. Fry, collected from rivers, are reared in ponds in association with other cyprinoid species. Hardy fish, able to stand transportation over long distances. Mid-water feeder, taking chiefly zooplankton during fry stage and partly vegetable, partly animal food as adult fish.

Megalobrama bramula (Cuvier and Valenciennes)

Vietnam: Ca ven

Distribution: Vietnam, Laos, South China

Body rhomboidal, compressed; height of body 2 times in standard length. Mouth prominent, eyes large, no barbels. Two strong, smooth, osseous rays in dorsal fin. Lateral line scales 57. Color of body brown, sides and belly silvery.

Freshwater river fish, suitable for culture in confined waters. Does not breed in ponds. Spawns from April to May. Fry collected from rivers and lakes, reared in ponds in association with other species. Supposed to feed mainly on aquatic vegetation.

Labeo collaris Nichols and Pope

Vietnam: Ca choi, Ca troi, Pa chan

Distribution: Vietnam, Laos, China

Body elongated, moderately compressed. Snout conical, mouth inferior with fe bly developed papillae on lower lip. Height of body 2.9 to 3.2 times in standard length. Color of body silvery with black-spotted scales above the pectoral fins, arranged in the form of a vertical band.

Freshwater river fish, suitable for culture in confined waters. Does not breed in ponds. Fry collected from rivers used for stocking ponds. Often reared in association with other species. Said to be a mid-water feeder mainly subsisting on planktonic organisms. Adult fish omnivorous.

Climbing perch. Anabas testudineus (Bloch)

India:	Undee collee, Pana eyri, Sennal, Coi, Corvu, Nga pri
Burma:	Nga bye ma.
Ceylon:	Kavaiya, Kavaiyan, Pana ayri Kendai
Thailand:	Pla mor, Pla mor thai, Pla sadet
Indonesia:	Betik, Betok, Betrik, Boreg, Puju puju, Pupuju, Bale baleng, Oseng
Philippines:	Atas, Puyo, Ararco, Liwalo, Tinikan, Piit, Puyo, Puyo puyo, Gutan
North Borneo:	Ikan karok
Malaya:	Puyu
Vietnam:	Ca ro
Cambodia:	Trey kranh

Distribution: India, East Pakistan, Ceylon, Burma, Thailand, Malaya, Philippines, Indonesia, South China

Body oblong, posteriorly compressed; head rather broad, mouth not protractile. Small conical teeth on jaws and vomer; gill covers serrated. Dorsal fin with 16 to 19 strong spines and 7 to 11 rays. Origin of dorsal before origin of anal fin. Caudal rounded. Lateral line 26 to 31 interrupted large scales. Color of body rifle-green, lighter on the belly. In young specimens usually four vertical bands on the body and a dark stripe from corner of mouth below eye. Often a large dark blotch on the side of the tail base, surrounded by bright, sometimes yellow rings. Maximum length 230 mm.

Essentially a freshwater river and swamp fish; in some regions adapted to life in estuarine environments. Breeds in confined waters. Suitable for cultivation in ponds, reservoirs and rice fields. Often occurs in cultivated waters as extraneous fish. Attains maturity when about 8 cm long, about 6 months of age. Spawning period during the monsoon or rainy season, India May to October, Indonesia December to May. Eggs yellow or whitish, buoyant, floating freely on the surface until they hatch. Embryos hatch out after 24 hours at a temperature of 28° C.

Larvae and young fry feed on phyto- and zooplankton in about equal parts. Large fry and adult fish feed on crustaceans, worms, molluscs and insects, which make up about 70 per cent of the bulk, algae and soft higher plants constitute about 25 per cent and the rest is organic debris. Has been observed to feed in rice fields on paddy grains but in ponds also eagerly takes white ants or dead forage fish.

Seldom reared alone but often in association with Trichogaster, Ophiocephalus and Clarias in ponds, reservoirs and rice fields with acid water. Hardy fish, able to live out of water for considerable periods by retaining water in the labyrinthiform organ. Able to resist long periods of unfavorable ecological conditions. Optimum water temperatures between 20° and 30° C, but resistant even to temperatures below freezing point. Attains in ponds a length of about 12 cm at the end of the first year, 20 cm at the end of the second.

Catfish. Clarias batrachus (Linnaeus)

India:	Kag ga, Mah gur, Magurah, Mangri, Ana meenu, Marpoo, Magurph
Ceylon:	Magura
Burma:	Nga kheo
Thailand:	Pla duk dam

Indonesia: Leleh, Ikan kalang, ikan maut, Pintet, Tjepi
Malaya: Keli
North Borneo: Ikan keli
Cambodia: Ca tre, Trey andeng
Vietnam: Ca tre trang
Philippines: Alabbiyog, Kawatsi

Distribution: India, Ceylon, East Pakistan, Burma, Malaya, Thailand, Cambodia, Vietnam, Indonesia, Philippines

Body elongate, head much depressed, mouth transverse four pairs of barbels. Head covered with osseous plates, covered with fine granular growth. Skin of body naked. Body dingy green or brownish on the back, lighter beneath. Vertical fins often with reddish margins. Maximum length over 400 mm.

Freshwater swamp and river fish, suitable for cultivation in confined waters. Often occurring as extraneous fish in ponds and rice fields, breeds in confined waters. Able to stand slightly brackish water. Spawning period during rainy season, in ponds throughout the year.

Young fry feed on Protozoa, small Crustacea, Rotifera and phytoplankton. Adult fish feed on insect larvae, shrimps, worms, fish and whatever organic debris that occurs on the bottom. Reared in ponds, tanks and rice fields in India, Pakistan, Malaya and Vietnam often in association with other Labyrinthici. Able to survive conditions fatal to most other kinds of fish; able to live in liquid mud and to burrow in moist soil; provided with accessory respiratory organs.

Length at the end of the first year about 20 cm, maximum length reached at the end of second year.

Catfish. Heteropneustes fossilis (Bloch)

India: Bitchu ka mutchee, Singi, Sheen-ee, Thai lee, Mar pu, Chela meenu Singee, Kahree meen, Lo har
Ceylon: Hunga, Kaha hunga, Shunken
Burma: Nga gyee, Nga khoo
Thailand: Pla cheet

Distribution: Pakistan, India, Ceylon, Burma, Thailand, Cambodia

Body elongate, head 6 times in standard length, barbels on upper jaw extend to the extremity of the pectorals. Origin of dorsal fin before the anterior third of the body. Anal and caudal fin separated by a notch. Color of body leaden, sometimes with two longitudinal yellowish bands. Maximum length 450 mm.

Freshwater river and swamp fish, suitable for cultivation in confined waters, swamps and weedy marshes. Spawns throughout the year. Feeds on Protozoa, Crustacea, worms, and insects which provide about 75 per cent of the diet, the rest consisting of algae and higher plants. Bottom feeder. Able to survive in very muddy water, or in wet soil for considerable periods, even out of water if the body is kept moist. Provided with an accessory respiratory organ. In confined waters the majority of stock attains a length of 20 cm at the end of the first year.

Tench. Tinca tinca Linnaeus

Distribution: Europe, Western Siberia.
Introduced into India, Indonesia, Japan and Ceylon.

Common pond fish in Europe, now occurring in Ootacamund Lake in South India, from where transplanted to various areas. About 1930 was widespread in West Java, Indonesia, but now scarce. Occasionally reared in Japan. In the Indo-Pacific Region feeds on diatoms, blue-green and filamentous algae, and on vegetable debris and about one-third of the bulk of food consists of aquatic animals including molluscs, worms, insects. Bottom feeder. Spawns at 16° C or more in ponds. The eggs are small (1 mm) with the average sized female producing about 200,000 eggs per pound of body weight.

The females are distinguished from the males by much weaker and shorter ventral fins and seemingly weaker pelvic bones. In Europe the growth is slower than carp, attaining:

at the end of first year a weight of 10 to 20 g
" " " " second " " " " 50 to 100 g
" " " " third " " " " 150 to 300 g

A maximum weight of 3 kg with a length of 40 cm has been recorded.

It may be cultivated in ponds with carp, the stocking rate being about 10 per cent of the number of carps.

Carnivores

Eel. Anguilla japonica Temminck and Schlegel

Japan: Unagi Ala unagi, O-unagi, Goma unagi
China: Pai shan
Vietnam: Ca thiet linh, Con luong

Distribution: Japan, China, Vietnam, Taiwan (Formosa)

Body very elongate, anteriorly cylindrical, posteriorly compressed. Head long, conical, moderately pointed, its length about 2.3 times in length of trunk. Skin covered with minute embedded scales which are linear in form and arranged in small groups at about right angles to those of the neighboring groups. Lateral line well developed. Color of body dark brown or yellowish brown above, rarely marbled, becoming abruptly paler below. Pectoral fins pale; dorsal, anal and caudal fins edged with black. Sometimes a series of whitish dots along lateral line.

Occurring in streams, lakes and estuaries. Suitable for cultivation in fresh and brackish water ponds. Breeds in sea, fry collected from estuaries or rivers. Collection period in Japan from February to April. Elvers, 6 to 7 cm in length, are caught when they try to ascend rivers. Reared in nurseries for a period of a half to two years to a length of 12 to 15 cm and sold to fish farmers for pond stocking. Eels about 15 cm in length can also be directly caught in rivers for further rearing in ponds. In ponds, reach, at the end of the first year, a length of about 30 cm and a weight of 100 to 200 g. The greater part of the stock is then sold for consumption.

Voracious fish, feeding in open water on insects, crustaceans, molluscs, and fish; in ponds completely depending on supply of artificial food. The conversion ratio of the usual foods, such as silkworm pupae, fresh and cooked fish, earth worms or crushed molluscs is about 5.5 to 1. Most suitable water temperatures for rearing between 20° C and 28° C. Often reared in association with common carp and grey mullet. Production depending on the amount of food supplied. Yields up to 15,000 kg per hectare are on record.

Cock-up. Lates calcarifer (Bloch)

India: Begti, Bekti, Dangera, Koliji, Fitadar, Khajura, Chemballi, Nari meen, Durruah, Bekkut, Painee meen, Koduwa, Panduchapa, Padugoppa, Todah
East Bengal: Kora, Baor
Ceylon: Modha, Modha koleya, Keduva
Thailand: Pla kapong, Pla kapong nam-chut, Pla kapong kao
Malaya: Kakap
Vietnam: Ca chem, ca vuot
Cambodia: Trey spong
Philippines: Kakab, Apahap, Bolgan
North Borneo: Ikan sulung-sung
Indonesia: Kakap, Pelak, Petehan, Pletekan, Telap, Tetehan, Tjabeh, Tjabik, Tjukil, Dubit, Djubit, Tekong, Tjakong, Tjateh, Kandjah, Pitja pitja, Kasa kasa, Gandja, Talangsur.

Distribution: Littoral waters of Persia, East and West Pakistan, India, Ceylon, Burma, Malaya, Thailand, Cambodia, Vietnam, Philippines, Indonesia and Australia.

Body oblong, moderately compressed, head depressed, upper profile more or less concave. Mouth oblique, lower jaw projecting. Gill cover finely serrated behind, with a strong spine at its angle and three to four spines along its lower border. Teeth in jaws, vomer and palatines. Two dorsal fins united at their bases, the first with seven to eight strong spines. Three spines in anal fin. Lateral line scales 52 to 61. Color of body greyish, greenish along the back, silvery beneath. Maximum length about 1,700 mm.

A typical fish of estuarine environments, ascending rivers for a distance of about 100 km from sea. Suitable for cultivation in confined waters, often occurring in ponds as extraneous fish. Does not breed in ponds, fry collected from rivers, creeks or lagoons. Feeds in open waters on fish; crustaceans might provide up to 75 per cent of the bulk of food. Column feeder; extremely predaceous, not suitable for cultivation in association with other commercial species. Reared in ponds in India and Thailand where it feeds on small fishes, prawns and shrimps. Attains a length of about 30 cm at the end of the first year, weight about 500 g. Production depending on the amount of food provided. Suitable for rough release in lakes and reservoirs.

Tarpon. Megalops cyprinoides (Broussonet)

Syn: Ox-eyed herring, Lady fish, Bastard mullet, India Tarpon

India: Punnikowa, Nahara, Cunnay, Moran kendai, Nhama
Ceylon: Illeya, Mareva
Burma: Nga tam youet

Thailand: Pla taluerk, Pla taluerk nam chuet
Malaya: Bulan bulan
North Borneo: Bulan bulan
Philippines: Bulan bulan, Nulan bulan, Buan buan
Vietnam: Ca chao
Indonesia: Bulan bulan, Seleh, Trupan, Kentera, Bandeng laut, Kampulan, Bale, hebo, Bale kebo

Distribution: Indian and Pacific Ocean

Body oblong, slightly compressed, mouth oblique, large, lower jaw prominent. Origin of dorsal midway between base of caudal and tip of snout. Last dorsal ray produced in a long filament. Axillary scale above pectorals and ventrals. Large eyes provided with narrow adipose eye lids. Teeth on jaws, vomer, palatines and tongue. Scales thin, along the lateral line about 40. Color of body silvery, bluish reflections on the belly. Dorsal, caudal and upper part of pectoral fins black. Maximum length more than 1,000 mm.

Primarily a marine fish, it enters fresh waters and gets naturally acclimatized to such habitats. Suitable for cultivation in confined waters. Does not breed in ponds. Larvae and fry, collected from estuarine waters can be transported over long distances and transferred directly to fresh water. Hardy quick-growing fish, often occurring as extraneous species in brackish water ponds. Dreaded predator, only usable as converter of coarse fish in lakes, swamps, reservoirs, and for angling ponds. Breeds throughout the year with a peak season during winter. Larvae resemble grass eels in shape.

Fry feed mainly on small crustaceans with restricted quantities of diatoms and filamentous algae. Food of adult fish consists of 50 to 55 per cent fish, 30 per cent crustaceans and the rest other aquatic animals with a small portion of vegetable matter.

Attains in freshwater ponds and tanks a length of about 35 cm at the end of the first year; but under very favorable conditions this length might be reached after 4½ months. In brackish water ponds the length at the end of the first year is about 40 cm. Reared only in India, in other countries considered as undesirable fish in ponds.

Snakehead or murrel. Ophiocephalus striatus Bloch

India: Moral, Sowl, Sol, Holi, Hal sola, Sohr, Marl, Kucchu meenu, Viral, Sowara, Wrahl, Owlu meenu, Seulo.
Ceylon: Lulla, Hal path maha, Virae
Burma: Nya yan
Thailand: Pla chon, Pla chorn
Malaya: Gabus
North Borneo: Aruan sakak
Vietnam: Ca lok, Ca trau, Ca sop
Cambodia: Trey ras
Philippines: Sulbus, Bukule, Haruan, Haluan, Lawag, Dalag, Bundaki
Indonesia: Gabus, Kutuk, Bajong, Deluk, Gapuran, Betul, Rutiang, Rajong, Tjingkong, Bako, Palompong, Tabian, Tumba, Rua, Behau, Haruan, Uruan, Aruwan, Bale salo, Tola, Kaju.

Distribution: From India, and from Ceylon to China and through Indonesia and Borneo to the Philippines.

Body cylindrical, compressed posteriorly, height 5 to 6 times in standard length. Head depressed, its upper profile somewhat convex, snake-like. Teeth in jaws, vomer and palatines. Origin of dorsal behind base of pectorals. Lateral line scales 52 to 57, with an abrupt curve downwards at about the 17th to 20th scale. Color of body, greenish, brownish to almost black on the back; white, creamy or light brown on the belly. Upper part of body has dark streaks and blotches, arranged in oblique bars. Lower parts have similar blotches at right angles to those on upper parts. Maximum length over 900 mm.

Freshwater river and swamp fish, capable of living in slightly brackish water. Suitable for cultivation in confined waters; often occurring in ponds, reservoirs and rice fields as extraneous fish. Breeds in ponds without particular measures. Reaches maturity when about two years old. Spawning period in India in May-June and in December-February; in Indonesia January-May, in Ceylon before and after the rainy season. Parent fish prepare a nest by biting off vegetation over a circular area in shallow water on the edge of the pond. Eggs are laid in a thin layer and carefully guarded by the male fish. Fertilized eggs measure 1.25 to 1.5 mm in diameter; larvae hatch out within three days, attain adult habits when about nine weeks old. Parent fish round up, guard and guide fry to suitable feeding grounds. Capable of living in foul water by virtue of accessory respiration. Can survive for months without water when buried in moist soil. Larvae and young fry feed on algae and protozoans. Young fish take small crustaceans along with a restricted portion of vegetable matter, adults are highly carnivorous dreaded predators of other pond fish. Reared in ponds and reservoirs in India and East Pakistan. Furnishes a part of the fish crop of swampy rice fields in Malaya, Thailand and Cambodia. Highly represented in the catch of trapping ponds in most countries of the region.

Snakehead or murrel. Ophiocephalus marulius Hamilton Buchanan

India:	Hoovina meenu, Purveral, Pumurl, Pula chapa, Coaree veral, Curavu, Kubrah, Sawl, Dowlah, Holee mach, Ha-al Gajal, Saal.
Burma:	Nga van daing
Ceylon:	Gangara, Ara, Kalu maha, Iru viral
Thailand:	Pla chon ngua hao

Distribution: India, Ceylon, East Pakistan, Burma, Thailand, Vietnam

Body cylindrical, compressed posteriorly, height about 7 times in total length. Head depressed, 16 rows of moderately sized scales between origin of dorsal fin and snout. Lateral line scales 60 to 70, descending for two rows of scales after the 16th to 18th scale. Color of body greyish-green on the back, belly orange colored, 5 or 6 cloudy vertical bands descending to below the lateral line, generally a darkish, white-edged blotch on the upper part of the base of the caudal fin. Anal and caudal fins have white spots. Young fish have a brilliant orange colored band passing from the eye to the middle of the tail. Maximum length about 1,200 mm.

Freshwater river fish, suitable for cultivation in confined waters. Breeds in ponds without particular measures. Breeding period in India from April to June, parental care and breeding habits similar to those of O. striatus. Fertilized eggs measure about 1.5 mm in diameter and are brownish in color. Fry become independent of parental care after about six weeks. Suitable for cultivation in tanks, irrigation wells and cisterns, if artificial foods are provided. Feeds on small fishes, frogs, tadpoles, water insects. Rate of survival in irrigation wells about 10 per cent, probably due to cannibalistic habits. Quick growing species. Two-months-old fry measure about 12 cm.

Snakehead or murrel. Ophiocephalus punctatus (Bloch)

India: Dhoalee, Phool dhok, Horava, Parakorava, Korava, Beli korava, Muttah, Gorissa, Gurria, Cartua gorai, Lata, Dullonga, Nga ain, Nga rynok, Chankee.
Ceylon: Mada ara, Mada kanaya, Mada kariya, Madaya, Korruvai
Burma: Nga panau

Distribution: India, Pakistan, Burma and Ceylon

Body cylindrical, compressed posteriorly. Head depressed, with 12 rows of scales between origin of dorsal and snout. Scales on top of head are of irregular shape. Lateral line slightly curved above the fourth anal ray. Color of body greenish on the back, yellow on the sides and the belly. A dark stripe along the side of the head; several bands downwards from the back to the middle of the body. Fins spotted, vertical ones with narrow light edge and dark basal band. Some specimens have black spots scattered over body and head. Maximum length about 300 mm.

Freshwater river and swamp fish, suitable for cultivation in confined waters. Breeds in ponds and tanks, spawning period, habits and parental care similar to other Ophiocephalus species. Highly predatory. Fry feed to a length of 5 mm mainly on unicellular algae, beyond this stage they show carnivorous tendencies. Up to 8 cm long fry feed on protozoans, rotifers, copepods and insects with diminishing quantities of vegetable matter. Larger fish show progressive preference for fish as food and in adults fishes might constitute 30 to 100 per cent of the total food consumed. Some Indian investigators hold the view that it is predominantly insectivorous and not destructive to other species in any large measure. Used in India for cultivation in ponds, reservoirs and wells.

Pangasius larnaudi Bocourt

Thailand: Pla tepo
Cambodia: Trey po khmau trachiek
Vietnam: Ca vo

Distribution: Thailand, Cambodia, Vietnam

Body elongate, compressed. Profile behind dorsal fin nearly straight. Mouth subterminal, snout prominent. Four barbels. Small dorsal fin with a strong denticulated spine; small adipose fin. Skin naked. Color of body greyish blue on the back, silvery on the sides and beneath, head light green. Conspicuous black spot above pectorals. Ventral and pectoral fins vermillion. Maximum length about 700 mm.

Freshwater river and lake fish, suitable for cultivation in confined waters. Does not breed in ponds. Fry collected from rivers for rearing in ponds, bamboo enclosures and cages. Collecting period August-September. Up to 10 cm long, fry stay in schools at the bottom of the water, coming to the surface at intervals to gulp air. Fry caught in river sections with slow current shaded by bushes and trees. Feeds in confined waters on almost any food offered. In Thailand fed on kitchen wastes, bananas, spoiled fish and fish wastes, cooked rice and rice brans, and soft plants. In Vietnam mainly fed on small cyprinoid fish, preferably in fermenting condition, supplemented by chopped bananas, rice bran, cooked maize and soft plants. Attains in ponds a weight of about 450 g at the end of the first year and 1 kg at the end of the second. When fed on fish and fish paste, fry weighing 100 g can grow up to a weight of 1 to 1.2 kg in 8 to 10 months. The maximum weight of fish in ponds or cages is about 1.5 kg.

Pangasius sutchi Fowler

Cambodia: Trey pra
Vietnam: Ca tra yeu

Distribution: Thailand, Cambodia, Vietnam

Body elongate, compressed. Mouth subterminal, four barbels. Dorsal fin with denticulated spine, small adipose fin. Color of body greyish-black, strikingly marked with a broad, straight dark band from the head to the base of the caudal fin and a curved dark band from the head to a point over the posterior part of the anal fin. The bands are separated from the blackish back and from one another by whitish inter-spaces. Dorsal and caudal fins with whitish edges. Anal fin white with a median black band. Maximum length over 1, 500 mm.

Freshwater river and lake fish, suitable for cultivation in confined waters. Does not spawn in ponds; fry collected from rivers for cultivation in ponds and cages. Spawning period March to May, fry collection period from August to September. In open waters mainly carnivorous, in ponds taking mixed food, fish, cereals and vegetable matter. Slower growing than P. larnaudi but capable of reaching a larger size. Reared in ponds, tanks, cages and pens (bamboo enclosures) in Thailand and Vietnam.

Pangasius micronemus Bleeker

Indonesia: Wagal, Wakal, Juaru, Djuara,/ Lawang, Rios, Rio
North Borneo: Patin
Thailand: Pla sawai, Pla sangkawart tong
Cambodia: Trey Chhviet
Vietnam: Ca thieu

Distribution: Indonesia, Malaya, Thailand, Cambodia, Vietnam and North Borneo.

Body elongate, compressed, prominent snout, mouth subterminal, rather small. Height behind dorsal fin more than 4 times in standard length. Four barbels. Small dorsal fin with osseous, denticulated spine of moderate strength. Color of body bluish grey on the back, lighter on the sides and below. Fins yellowish, part of caudal and dorsal fins black. Maximum length over 500 mm.

Freshwater river fish, suitable for cultivation in confined waters. Does not spawn in ponds; fry collected from rivers for cultivation in ponds and cages. Carnivorous in open waters, more or less omnivorous in ponds. Reared in ponds, bamboo enclosures (pens) and cages in Thailand and Vietnam. Esteemed food fish in Indonesia but not yet used for pond culture. Quick-growing valuable pond fish for regions where inexpensive artificial food is available.

Pangasius sanitwongsei H.M. Smith

Thailand: Pla thopa

Distribution: Thailand

One of the largest freshwater fishes; maximum length more than 2, 500 mm. Occasionally reared in pens and ponds as for other Pangasius species; does not spawn in captivity, fry collected from rivers. Voracious predator.

Ten pounder. Elops machnata (Forskal)

Distribution: Red Sea, Indian Ocean, Pacific Ocean

Body elongate, height 5 to 5.6 times in standard length. Head conical, lower jaw projecting, fine teeth on jaws, vomer, palatines and tongue. Lateral line scales 94 to 98. Color of body silvery, fins greyish. Maximum length 700 mm.

Marine fish, which in Hawaii attains significance as part of the crop of brackishwater ponds. Fry enters ponds with incoming tidal water. Often considered undesirable as pond fish but studies have indicated that it is not so predaceous as generally believed. Feeds in ponds mainly on crustaceans and small fish.

Related species: Elops hawainsis T. Regan, occurring as extraneous fish in brackish water ponds in Indonesia.

Elops saurus Bleeker, acclimatized to freshwater conditions in India.

Both species are highly carnivorous.

Bream. Parabramis pekinsis (Basilewsky)

Hong Kong: Bin yu, Tong bin
China: Yu pin tze

Distribution: South Central and North China

Body oblong, compressed, height about 2.8 times in standard length. Snout blunt, upper jaw protractile. No barbels. Teeth in throat. Lateral line scales 35 to 63. Maximum length over 300 mm.

Freshwater river fish, suitable for cultivation in confined waters, as pond fish of minor importance. Fry mostly collected from rivers and lakes. Breeds in large ponds without specific measures. Adult fish feed on aquatic insects, worms and small fish, plants are taken as supplementary food. Cultivated in China only.

Goldfish. Carassius auratus Linnaeus

China: Chi yu, Kam yu, Tsak yu.
Japan: Funa
Vietnam: Ca diec
Indonesia: Tambra mas, Ar ar

Distribution: China, Japan, Vietnam.
Introduced into Indonesia, Thailand and Pakistan

Body oblong, moderately compressed, mouth terminal without barbels. Height about 2.5 times in standard length. Dorsal fin long with the last simple ray ossified and serrated behind, its origin opposite to that of ventrals. Lateral line scales 25 to 30. Wild breeds dark olivaceous in color; domesticated, it forms many varieties and monstrosities. Gold and orange colored varieties revert to darkish green or olivaceous color when cultivated under natural conditions. Can easily be differentiated from common carp by teeth in a single series of four in the throat and by the absence of barbels.

Fry feed on phyto- and zooplankton, young fish and adult feed on chironomids, tubifids, vermes and crustaceans, supplemented by a comparatively small amount of vegetable matter.

Slow-growing fish of little economical value. Suitable for cultivation under tropical conditions between 200 and 1,000 m above sea level. Spawns in captivity. Eggs about 1 mm in diameter, adhesive, attached to aquatic plants or artificial collectors. Attains in ponds a weight of 250 g at the end of the first year. Production of manured ponds about 400 kg per hectare. Often reared in association with other species or kept as ornamental fish supplementary to a crop of quick-growing fish.

Ornamental varieties reared commercially in some areas of China and Japan, shipped as aquarium fish all over the world. In some of the aquarium varieties the dorsal fin is reduced to a serrated ray with some soft rays, or the dorsal fin is absent. Caudal fin is often three- or four-lobed. Eyes may be very large and protruding or the vertebral column deflected. Varieties known as the "Lionhead", the "Telescope fish" or the "Pearl scale" were previously available from Shanghai, Tien Tsin (China) and from Nara (Japan). They often fail to survive the heat in tropical countries.

Rainbow trout. Salmo gairdneri Richardson

Japan: Nijimasu
Indonesia: Ikan forel

Distribution: Native in the rivers on the West Coast of North America from Baja, California, to Alaska. Introduced and now cultivated in India, Ceylon, Japan and Australia. Stock in Indonesia was lost during the war.

Body elongate, moderately compressed, height about 3.8 times in length. Head short, about 4 to 5 times in total length. Mouth comparatively small, two irregular series of teeth on the vomer. Lateral line scales 135 to 150. Many sub-species with deviating features. Color of body variable depending on sex, age and environment. Typical adult specimens are bluish on the back and the sides, profusely and irregularly spotted with black. Along the lateral line a red band and blotches, belly whitish, nearly plain of color. Maximum length over 700 mm.

River and lake fish, outside the Indo-Pacific Region often cultivated in confined waters. Does not breed in ponds, artificial fertilization of eggs and hatching possible. Spawns in the region during winter or monsoon season. Eggs deposited in shallow pools on gravel banks in streams. Artificial hatching applied in all countries where rearing customary. Fry feed mainly on zooplankton, half-grown and adult fish take aquatic and terrestrial insects; worms, snails, crustaceans and small fish. Spleen, liver, meat, slaughterhouse refuse, fish, etc., are given as artificial foods in hatcheries.

In tropical and subtropical regions rainbow trout can thrive in streams and lakes, and very occasionally also in ponds if the average temperature of the water is 14° C or less, and maximum 24° C.

Successful rearing is generally only possible in clear water at altitudes of more than 1,500 m, in exceptional cases at 1,000 m. In the Indo-Pacific Region rainbow trout is a game fish of minor importance; its suitability as a pond fish has not been studied.

Brown trout. Salmo trutta Linnaeus

Distribution: Cold and temperate regions of the Northern Hemisphere, descending into Asia as far South as the Hindu Kush. Introduced and presently reared in India and Australia.

Body comparatively short and stout, height about 4 times in standard length. Length of head about 4 times in standard length. Dorsal fin at the middle of the body. Caudal emarginate in young specimens but nearly truncate in larger fish. Large scales. Color of body brownish-black, varying with environment, food and race. Numerous red and black spots on head, body and dorsal fin. Black spots are circular or X-shaped, some of them might have a pale border. Usually a yellowish margin on the front of the dorsal and the anal fin and the outer border of the ventrals. Maximum length over 1,000 mm.

Brook, river and lake fish, outside the Indo-Pacific Region often cultivated in ponds. Does not breed in ponds; artificial fertilization and hatching of eggs possible. Spawns in the Indo-Pacific Region during winter or monsoon period. Eggs deposited in crevices between stones and gravel. Parent fishes cover the eggs to some extent with gravel. Adult fish feed on insects and their larvae, worms, molluscs, crustaceans and fish. A certain part of the food is of terrestrial origin.

Cultivated in the region for stocking streams at heights of more than 1,000 m above sea level, with maximum temperature of 20° to 22° C. Game fish, little importance as pond fish.

Sockeye salmon. Oncorhynchus nerka (Walbaum)

Japan: Hime masu, Kabacheppo

Distribution: Pacific coast of North America, Siberia, Russia and Japan.

Body slender, frequently bright blue in color on the back, devoid of spots, sides silvery. At spawning time the body of the fish becomes blood red and the head light green. The male develops a prominent hook at the jaw. Caudal fin lunate. Maximum size more than 1,000 mm.

Eggs obtained by stripping females caught in rivers. Fry reared in nurseries used for stocking operations. Unsuitable for pond culture.

Oncorhynchus rhodurus Jordan and McGregor

Japan: Amenoue, Ame, Amago

Distribution: Southern half of Japan

Body elongate, moderately compressed, head conical, snout blunt. Color of body dark blue on the back, whitish below, strong silver shading all over body. During spawning period body attains a brownish tinge with irregular shaped marking of crimson-red color. Maximum size about 500 mm.

Lake and stream fish, not suitable for cultivation in ponds. Spawns in November in streams. Eggs 3.3 to 3.8 mm in diameter, hatching in 30 to 65 days. Attains sexual maturity in three to five years. Eggs can be stripped and artificially fertilized. Predator with a slow rate of growth. In streams seldom attains a length of more than 250 mm.

Mountain trout, Salvelinus malma (Walbaum)

Japan: Oshorokoma, Iwana

Distribution: Northern Pacific, Japan. In the southern parts of Japan restricted to the cold headwaters of rivers.

Body moderately elongate, compressed. Dorsal profile broadly curved. Head short and stout with blunt snout. Color of body brownish on the back, much paler below. Pale spots of unequal size profusely scattered over the body. Dorsal fin edged by a broad blackish band. Adipose fin with narrow dusky edge. Caudal fin dusky along posterior margin, other fins pale.

Freshwater river and stream fish, landlocked. Spawns in streams and propagates freely. Stripping of eggs and artificial fertilization possible. Fry reared in nurseries used for stocking operations.

Pond smelt, Hypomesus olidus (Pallas)

Japan: Wakasagi, Amasagi

Distribution: Japan

Body slender, flattened. Head more or less pointed. About 60 scales along the lateral line. Color of body light grey with yellowish tinge. Dark lateral band with silvery shading. Maximum size over 120 mm.

River fish inhabiting estuarine and freshwater sections. Suitable for cultivation in ponds. Attains sexual maturity in the first year of life. Spawns in rivers from January to March. Eggs can be stripped, shipped after fertilization over long distances. Used for stocking lakes and ponds.

Sand goby. Oxyeleotris marmoratus (Bleeker)

Indonesia: Bakatut, Bakut
Thailand: Pla bu, Pla bu sai
Cambodia: Trey damrey
Vietnam: Ca bong tuong, Ca bong cao
North Borneo: Batutu

Body very elongate, head blunt. 70 to 90 scales in longitudinal series. Color of body yellowish, marbled with brown in large patterns with brown stripes along the rows of scales. Maximum length about 500 mm.

Freshwater river and swamp fish, suitable for cultivation in confined waters. Spawns in ponds without particular measures. Reared in ponds in Malaya, Cambodia and Vietnam, often in association with other species. Not cultivated in Indonesia. Attains a weight of about 900 g in one year, in ponds. Fry and adult feed mainly on aquatic insects, molluscs and crustaceans.

Freshwater shark. Wallago attu (Bloch and Schneider)

India: Wah-lah Vale, Vallah, Bale meenu, Mul-la, Pikee, Jerikee, Boyali, Boalli, Gwali, Mullee, Bawali, Shivada, Pari.
Thailand: Pla khao
Indonesia: Djambal, Tjangop, Limpok, Tjaba, Lika, Lika walu
Vietnam: Ca leo muon, Ca leo sinh
Cambodia: Trey sanday
Ceylon: Walaya

Body elongate, compressed, height 5 to 7 times in standard length. Head broad, snout spatulate, two broad bands of large teeth. Lower jaw prominent. Two pairs of barbels. Dorsal fin very short, without spines. Skin naked. Color of body blackish or grey on the back, lighter below. Fins dusky. Maximum length over 500 mm, up to 1,000 mm in Ceylon.

Freshwater river, lake and swamp fish, suitable for cultivation in confined waters. Sometimes descending in rivers into the tidal zone. Spawns during monsoons in inundated marginal areas of rivers. Eggs 1.2 to 1.5 mm in diameter, swelling up to about double that size. Embryos hatch out after 14 to 20 hours. Adult characters attained after seven days. Extremely voracious carnivore. Fry feed on fish 40 per cent, insects 30 per cent, crustacea 10 per cent, and algae 20 per cent. Adult fish feed almost exclusively on aquatic animals, chiefly fish. Not suitable for cultivation in ponds, but often occurring in reservoirs, especially those which are subject to periodical flooding. Probably suitable for stocking swamps, marshes, etc., to convert small size coarse fish into food fish.

English perch. Perca fluviatilis Linnaeus

Distribution: Europe. Introduced into Australia, now occurring in streams in New South Wales, Victoria, Queensland, Tasmania and Western Australia.

Body moderately elongate, compressed. Body covered with small rough scales, upper part of head smooth and scaleless. Long spine on gill cover. Coloration varies with locality, age, sex and season. Body greenish-yellow on the back, belly white. Five or more dark vertical bars on the sides, sometimes bifurcated above. Dorsal fin greyish black, pelvic fins reddish. Maximum length about 500 mm.

River and lake fish capable of living in brackish water; suitable for cultivation in confined waters. Spawns in Australia during July and August. Eggs are laid in long strings or ribbons, attached to aquatic plants. Eggs are enclosed in sheaths. Through these sheaths water circulates by means of small apertures and a central cavity. Larvae feed on infusoria; fry and adult fish feed on worms, insect larvae and small fish. Attains a weight of 1.8 to 2 kg. Seldom used for pond culture, tend to lead to dwarf populations.

Kissing Gourami. Helostoma temmincki C. and V.

Java:	Tambakan, Poni
Sumatra:	Sapil, Tabakang
Borneo:	Biawan
Celebes:	Ikan Samarinda
Malaya:	Tambakan, Temakang
Thailand:	Pla ikoh, Pla itan, Pla mor tan, Pla bai tan, Pla wee, Pla wi

Distribution: Java, Sumatra, Borneo, Malaya, Thailand. Transplanted to Celebes and Ceylon.

Body oblong-oval, compressed. Very small protractile mouth with thick lips. Eye on level with angle of mouth. Dorsal and anal fins consisting of spinous and soft parts. Ventrals with strong spine and five rays. Small scales. Lateral line 44 to 48, interrupted below soft dorsal. Body olivaceous or greyish on the back, lighter beneath. Faint longitudinal stripes following the rows of scales. Maximum length about 300 mm.

Freshwater river and swamp fish, suitable for cultivation in ponds in tropical climates. Breeds in ponds if appropriate measures are taken.

Spawns, for the first time when 12 to 18 months old, at a length of about 20 cm. Well-fed breeders spawn every three months. Eggs, 1 mm in diameter, contain oily globules, pelagic, yellowish white when newly ejected, turning black the next day. Embryos hatch out 24 hours after fertilization, larvae stay hidden under plants or floating objects until the third or fourth day. A female, 200 g in weight, produces 1,000 to 7,000 fry at each spawning; no specific spawning season.

Fry and adults feed on phyto- and zoo-plankton. Mid-water and surface feeder, growing rapidly if large quantities of Flagellatae, Dinoflagellatae, Protococales, Desmidiaceae and Diatomeae are available. In ponds will take artificial foods such as rice bran, and starch of cassava roots. Generally cultivated at altitudes not exceeding 750 m, most suitable temperature of water 25° to 30°C. Resistant to low oxygen tension through accessory respiration. Annual production of manured ponds about 500 kg per ha.

CLASSIFIED LIST OF CULTIVATED SPECIES

Scientific name	Family	Country where cultivated	Environment
1. Elops machnata (Forskal)	Elopidae	Hawaii	xx
2. Megalops cyprinoides (Broussonet)	"	India	x
		Ceylon	xx
3. Chanos chanos (Forskal)	Chanidae	Ceylon	xx
		India	♦
		Indonesia	♦
		Vietnam	xx
		Philippines	♦
		Formosa	♦
		Hawaii	xx
4. Salmo trutta L.	Salmonidae	Australia	**
		India	**
		Ceylon	**
		Japan	**
5. Salmo gairdneri Richardson	"	Australia	**
		India	**
		Ceylon	**
		Japan	**
6. Salvelinus malma (Walbaum)	"	Japan	*
7. Oncorhynchus nerka (Walbaum)	"	Japan	*
8. Oncorhynchus rhodurus Jordan and McGregor	"	Japan	*
9. Plecoglossus altivelis Temminck and Schlegel	Plecoglossidae	Japan	*
10. Hypomesus olidus (Pallas)	Osmeridae	Japan	*
11. Anguilla japonica Temminck and Schlegel	Anguillidae	Japan	*
12. Cyprinus carpio L.	Cyprinidae	Ceylon	**
		India	**
		Malaya	**
		Indonesia	**
		Thailand	**
		Cambodia	**
		Vietnam	*
		China	*
		Japan	**
		Philippines	**
		Australia	**

xx Brackishwater indigenous species
x Species acclimatized to fresh water
* Freshwater indigenous species
** Freshwater exotic species
♦ Both brackishwater indigenous and acclimatized to fresh water

Scientific name	Family	Country where cultivated	Environment
13. Carassius auratus L.	Cyprinidae	China	*
		Vietnam	*
		Thailand	**
		Japan	*
		Indonesia	**
		Pakistan	**
14. Carassius carassius (L.)	Cyprinidae	India	**
		Japan	**
		China	**
		Indonesia	**
15. Puntius javanicus (Bleeker)	"	Indonesia	**
		Thailand	**
16. Puntius schwanefeldi (Bleeker)	"	Indonesia	**
		Malaya	**
17. Puntius belinka (Bleeker)	"	Indonesia	*
18. Puntius orphoides (C. and V.)	"	Indonesia	*
19. Barbus carnaticus Jerdon	"	India	*
20. Barbus (Lissochilis) hexagonalis Mc Clelland		India	*
21. Labeo rohita (Hamilton Buchanan)	"	India	*
		Pakistan	*
22. Labeo calbasu (Hamilton Buchanan)	"	India	*
		Pakistan	*
23. Labeo fimbriatus (Bloch)	"	India	*
24. Labeo kontius (Jerdon)	"	India	*
25. Labeo collaris Nichols and Pope	"	Vietnam	*
26. Labeo bata (Hamilton Buchanan)	"	India	*
27. Labeobarbus tambroides (Bleeker)	"	Indonesia	*
28. Cirrhina mrigala (Hamilton Buchanan)	"	India	*
		Pakistan	*
29. Cirrhina cirrhosa (Bloch)	"	India	*
30. Cirrhina molitorella (C. and V.)	"	China	*
		Malaya	**
		Thailand	**
31. Cirrhina reba (Hamilton Buchanan)	"	India	*

	Scientific name	Family	Country where cultivated	Environment
32.	Catla catla (Hamilton Buchanan)	Cyprinidae	Ceylon	**
			India	*
			Pakistan	*
33.	Ctenopharyngodon idellus (C. and V.)	"	China	*
			Vietnam	**
			Thailand	**
			Malaya	**
			Ceylon	**
			Japan	**
34.	Mylopharyngodon piceus (Richardson)	"	China	*
			Vietnam	*
			Thailand	*
			Japan	*
35.	Mylopharyngodon aethiops (Basilewsky)	"	Vietnam	*
36.	Hypophthalmichthys harmandi Sauvage	"	Vietnam	*
37.	Hypophthalmichthys molitrix (C. and V.)	"	China	*
			Formosa	**
			Thailand	**
			Malaya	**
			Japan	**
			Ceylon	**
38.	Aristichthys nobilis (Richardson)	"	China	*
			Thailand	**
			Malaya	**
			Japan	**
39.	Squaliobarbus curiculus (Richardson)	"	Vietnam	**
40.	Megalobrama bramula (C. and V.)	"	Vietnam	**
41.	Osteochilus hasselti (C. and V.)	"	Indonesia	*
			Malaya	*
			Thailand	*
42.	Osteochilus thomassi (Day)	"	India	*
43.	Parabramis pekinensis (Basilewsky)	"	China	*
44.	Tinca tinca L.	"	India	**
			Indonesia	**
			Japan	**
			Australia	**
45.	Thynnichthys sandkhol (Sykes)	"	India	*

	Scientific name	Family	Country where cultivated	Environment
46.	Wallago attu (Bloch and Schneider)	Cyprinidae	Pakistan	*
47.	Clarias batrachus (L.)	Clariidae	Malaya	*
			Pakistan	*
			Cambodia	*
48.	Heteropneustes fossilis (Bloch)	Heteropneustidae	Pakistan	*
49.	Pangasius sutchi Fowler	Pangasidae	Vietnam	*
			Thailand	*
50.	Pangasius micronemus Bleeker	"	Vietnam	*
51.	Pangasius larnaudi Bocourt	"	Vietnam	*
			Thailand	*
52.	Pangasius sanitwongsei Smith	"	Vietnam	*
53.	Ophiocephalus striatus Bloch	Ophiocephalidae	India	*
			Indonesia	*
			Malaya	*
			Cambodia	*
54.	Ophiocephalus marulius Hamilton Buchanan	"	India	*
			Pakistan	*
55.	Ophiocephalus punctatus (Bloch)	"	India	*
			Pakistan	*
56.	Helostoma temmincki C. and V.	Helostomidae	Indonesia	*
			Malaya	*
			Thailand	*
			Ceylon	*
57.	Osphonemus goramy (Lacépède)	Osphenemidae	Indonesia	*
			India	**
			Malaya	**
			Thailand	**
			Philippines	**
			Ceylon	**
58.	Trichogaster pectoralis (Regan)	"	Thailand	*
			Indonesia	**
			Malaya	**
			Philippines	**
			Pakistan	**
			Ceylon	**
59.	Trichogaster trichopterus (Pallas)	"	Vietnam	*
60.	Anabas testudineus (Bloch)	Anabantidae	Vietnam	*

	Scientific name	Family	Country where cultivated	Environment
61.	Mugil cephalus L.	Mugilidae	China	x
			Hawaii	xx
			Hong Kong	♦
			India	♦
			Japan	xx
62.	Mugil tade Forskal	"	India	♦
			Pakistan	xx
			Indonesia	xx
63.	Mugil corsula Hamilton Buchanan	"	India	x
64.	Mugil dussumieri C. and V.	"	India	xx
			Pakistan	xx
			Indonesia	xx
65.	Perca fluviatilis L.	Percidae	Australia	**
66.	Lates calcarifer (Bloch)	Latidae	India	♦
			Pakistan	♦
			Thailand	x
67.	Tilapia mossambica Peters	Cichlidae	Indonesia	**
			Malaya	**
			Thailand	**
			Philippines	**
			Ceylon	**
			India	**
			Pakistan	**
			Formosa	**
			Vietnam	**
68.	Etroplus suratensis (Bloch)	"	India	♦
69.	Oxyeleotris marmoratus (Bleeker)	Eleotridae	Malaya	*
			Vietnam	*

PROCUREMENT OF STOCK

Breeding Habits of Cultivated Fishes

The fecundity of the fishes that practise parental care may not be high, but they breed several times a year and, because of the protection afforded to the eggs and fry, some of the species can keep up a high population level. All these fishes breed in both lentic and lotic waters and it is relatively easy to provide them with the breeding requirements, such as nest building material or suitable substrate for the attachment of eggs.

Probably to compensate for the great loss of progeny that may occur as a result of unfavorable hydrological conditions or predation, the fecundity of fishes that do not practise parental care is fairly high.

The breeding requirements of some of these fishes are rather complex and our knowledge of the optimum conditions for their spawning is far from complete. The Chinese carps, except the common carp, have not been definitely observed to breed in localities other than their home waters in China. Even though it has been reported (Kuronuma, 1954) that fry of grass carp and silver carp have been collected from certain rivers in Japan, it has not yet been possible to determine which particular factor, or combination of factors, when provided in a confined area, will induce them to spawn. The cultivated carps of India and Pakistan breed in the rivers during the monsoons or occasionally during off-season freshets. The catla breeds only once a year during the South-west monsoon in north Indian rivers during the two monsoon seasons that occur there. This would appear to show that the floods and the subsequent changes in hydrological conditions have a profound influence in inducing the carps to spawn. The factors that are believed to govern the spawning of the major carps are summarized elsewhere but as in the case of Chinese carps it has not yet been possible to determine with certainty what actually does induce mature fish to spawn. The breeding requirements of the carps and the kissing gourami cultured in Indonesia are not very complex. If well-oxygenated running water is provided, fishes like the nilem (Osteochilus hasselti) and tawes (Puntius javanicus) will spawn. The former needs clear water, whereas the latter prefers slightly turbid water. The matamerah (Puntius orphoides) breeds when a good supply of well-oxygenated water is available and suitable plants are provided for the attachment of eggs.

The salmons, trouts, mullets and eels are all essentially migratory fishes that move to their specific spawning grounds during particular seasons to breed. The trouts and salmons ascend the rivers and breed generally in streams where there are suitable substrata on which to deposit the eggs and where there is well-oxygenated clear water. The milkfish is believed to migrate into deeper waters of the sea for spawning; it has not been observed to breed or even attain sexual maturity in any other type of environment. This is also the case with the salt-water mullets though they may attain maturity in brackishwater ponds. The cultivated eel (Anguilla japonicus) is catadromous in habit, it spawns in the deep seas. The leptocephali are drifted to the coast where they develop into elvers.

Possibilities of Artificial Propagation

The fact that some of the important cultivated fishes spawn only in rivers and others only in the sea makes it necessary for the fish farmer to obtain stocking material from natural waters. Attendant on this is the effort to collect, sort, condition and transport the material to fish farms. If the fishes could be induced to breed in confined waters, such as ponds, the procurement of stocking material could be considerably simplified. The provision of the optimum hydrological or ecological conditions that induce the fish to breed may make this possible.

Remarkable success has been achieved in this respect with the common carp, some of the Indonesian carps, the gourami, and other species. But due to lack of adequate knowledge of the breeding requirements this has not yet been possible with other cultivated species. Some of these become sexually mature in confined waters, but for want of the essential stimulus they do not breed in such areas. Many of the cultivated fishes, such as salmons, trouts, the Chinese carps and nilem can be stripped to obtain the ova and the milt. But in some, such as the major carps of India and Pakistan, attempts in this direction have so far been unsuccessful.

The secretion of the pituitary gland of the fish appears to induce ovulation and spawning. The sexual play of the mature fishes in the spawning grounds in the presence of optimum hydrological and ecological conditions may stimulate this secretion. The administration of the extract from the anterior lobe (hypophysis) of the pituitary gland to induce spawning or enable stripping is now successfully practised in some Western and South American countries, and some preliminary experiments in this direction have been conducted in the Punjab and Formosa.

Artificial propagation of cultivated fishes has been developed to a high level of perfection in many advanced countries. In view of the fact that many of the popular cultivated fishes of the Indo-Pacific region do not breed in confined waters, the need to adopt artificial methods of propagation may appear obvious, but a consideration of the basic object of fish culture in this area indicates its impracticability on a commercial scale. In these densely populated areas it is essential that the produce should be as cheap as possible and well within the reach of poor farmers whose capacity to invest capital is very limited. Fry could possibly be artificially produced, but there is a consensus of opinion among fishery biologists that the production from natural spawning is definitely superior to the meager production of artificial hatching. Fishery management agencies are now largely in favor of improving spawning grounds and encouraging pond breeding to increase the supply of stocking material. In most countries of the Indo-Pacific region this fact has been fully realized by practical fish culturists.

Possibilities of Pond Breeding

While the improvement of spawning grounds is an essential part of inland fisheries management, pond breeding of fishes is the concern of the fish culturist. As will be described later in this chapter, it is possible to develop methods of breeding certain species in ponds by providing their essential breeding requirements. The major carps of India and Pakistan do spawn in special bunds in which riverine conditions are simulated, but the construction of these is possible only in few a localities and moreover the maintenance of such bunds is not within the economic capacity of the average fish farmer. Further, as the exact breeding requirements of these fishes are not fully known there is a considerable element of chance in the operations. The need for intensive scientific investigations on the matter cannot therefore be over-emphasized. There is great scope and need for researches on the fishes that are bred in ponds. At present there is only some empirical knowledge of the feeding and the treatment to be given to brood fish in order to reach maturity; and very little is known about the factors that induce a fish to spawn more often in ponds than in natural spawning grounds. The common carp generally breeds only once in a year. But in Indonesia and Malaya it is reported that successful practices of brood fish selection, segregation of sexes, special feeding and provision of material for attachment of eggs are followed to induce them to breed several times a year. The scientific principles underlying the methods are not clear, and intensive research on these aspects will be of immense value in the development of fish culture.

In the Indo-Pacific region, stock for fish culture is obtained:

(1) by collecting fertilized eggs from the breeding grounds;

(2) by collecting spawn, fry or fingerlings from natural waters;

(3) by breeding fish in confined waters;

(4) by artificial fertilization.

The term stock denotes the earliest development stages with which culture operations are started. Culture might start with spawn. fry or fingerlings and so the term may mean any or all of these stages.

Three types can be distinguished, namely freshwater stock for culture in fresh water. saltwater stock for culture in fresh waters, and saltwater stocking material for culture in brackish waters.

Collection of Freshwater Stock

Carp Eggs and Fry in China

Methods of Collection. The fish fry trade in China is a well-organized industry giving employment to a large number of people, of whom "fry experts" and their assistants form the most skilled personnel. The trade is usually carried out by legally constituted companies which establish fry collection stations and headquarters where the transactions relating to sale, etc., are conducted.

The main sources of supply are the West River and the Yangtse. Practically all fry for the export trade come from the West River and are shipped by way of Hong Kong. The localities on the West River where fry are collected in quantities are situated in Kwangsi and Kwangtung provinces. Cheung Chow and Shiu Hing are the centers from which come at least 80 percent of the total produce of the West River. Here the spawning season extends from the middle of May to the end of June. At the end of July fry of most of the cultivated species become rare, except those of mud carp which still occur in large quantities in August and early September.

At each collection station ten to twenty rows of high frames are constructed on the banks of the rivers, during April. These frames are made of 10 to 16 poles 10 m long, fixed vertically at distances of about 3 m and strengthened by three or four poles of fir or bamboo, fixed horizontally at intervals of about 1.3 m. To this framework are fastened 10 to 15 conical bag nets about 5 m long made of a type of fine-meshed cloth. The mouth of the net has a circumference of about 4.5 m, and the codend about 1.2 m. The codend is tied to a finer meshed netting receptacle, which measures about 120 cm x 30 cm x 30 cm which is kept afloat in an oblong wooden framework. The net proper is also kept afloat by inserting a wooden pole into the bag. The eggs, larvae or fry, carried by the water into the net, collect in the receptacle at the codend. The dimensions of the gear vary with localities, but the general technique of collection is the same. The fishermen of Cheung Chow use troughs made of split bamboo instead of the conical bag nets. These troughs have the shape of a half cone, 3 m long and 1.1 m wide at the mouth. The net receptacle attached to the codend is of the same pattern as that of the receptacle described above. The eggs are transferred by means of dipnets from the receptacles into live wells or "netting reservoirs", 1.6 m x 1.3 m x 1.3 m in size, suspended on wooden frames. The dip net is of cloth with a rattan or bamboo ring reinforcing its mouth, its handle is about 20 to 25 cm long, and the net itself is about 25 cm deep. The live wells are towed to the shore and the eggs transferred to waterproof baskets by

means of dip nets. The baskets measure 0.9 to 1.2 m in diameter, about 1.1 m in depth and are made of bamboo rendered waterproof by a thick mixture of glue and cow dung smeared inside and dried over a charcoal fire. A catch consisting of fry is transported in the baskets to the nursery ponds for sorting and distribution. But if the collection consists of eggs, as in Heng Yang on the Siang River of Hunan Province and in Tsaichi near Ichang of Yangtse River in Hopei Province, they are hatched before introduction to nursery ponds. Hatching is done in "hatching boxes", similar to the fry netting reservoirs or live wells referred to above, approximately 2 m x 1 m x 5.5 m and are anchored at some sheltered spot in the river or at the mouth of a small tributary where the water is comparatively clear. About one-third of the "box" is kept floating above the surface of the water by means of a wooden framework. In bright sunny weather, when the temperature is fairly high, the eggs hatch out in two or three days. The fry are held in the "hatcheries" for three days.

Sorting Fry. Since the collections taken by the nets may consist of fry of several species of carp and of some other fishes, there must be a sorting before they can be traded, stocked and reared. This is especially necessary because the demand for the quick-growing species of carps, such as the big head, Aristichthys nobilis, and the grass carp, Ctenopharyngodon idellus, is greater than that for the other species taken.

A preliminary estimation of the composition of the catch is made in the field itself. A sample of the catch is taken from the live well in a "fish fry dish"* with some water and the percentage of each type is determined by examining the movements, shape, etc., of the fry. According to Lin (1950) the following are the characters that enable the experts to determine the species:

(1) Silver carp – (Hypophthalmichthys molitrix) - always swimming in the upper layer of water with occasional stops while swimming; head small, interorbital space narrow; body short with small roundish air bladder; color dark gray, not so transparent as the big head.

(2) Big head - (Aristichthys nobilis) - swimming in a slow and steady manner; air bladder roundish; body long and robust, head and eyes large.

(3) Grass carp - (Ctenopharyngodon idellus) - swimming in the middle layer of water with occasional pauses; color dark, eyes medium, air bladder small, roundish, body short, tail pointed.

(4) Black carp - (Mylopharyngodon piceus) - swimming like the grass carp; air bladder long; body long, eyes large; head depressed, triangular-shaped.

(5) Mud-carp - (Cirrhina molitorella) - swimming in a sluggish manner near the bottom or along the edge of the dish, eyes small, roundish, body small, slender, pinkish in color, a spot on the tail.

(6) Mandarin fish - (Siniperca chuatsi**) - swimming at the bottom, usually 10 to 20 mm in length; mouth large; color dark.

(7) Common carp and goldfish - (Carassius auratus) - color dark, body short with long dorsal fin, fry 6 or 7 days after hatching, 5 mm long with a black speck at the base of the tail fin.

(8) Bream - (Parabramis pekinensis) - swimming in the middle layer of water; color dark, a dark speck on front part of dorsal fin; active fry.

* Fish fry dishes are made of light wood such as Bombax, and painted with white enamel. They are generally 25 cm in diameter and 4.5 cm in depth, or 22.5 cm in diameter and 6 cm in depth.

** The fry of this fish are usually found among carp fry.

As soon as the fry are received at the nursery, small samples are taken from the containers and each sample is placed in a bowl containing clear water. Each type of fry in the bowls is counted and from this the percentage of each type is calculated. If there are customers to buy the fry direct, they are sold on the spot. In the absence of customers, the fry are sorted out according to species. The whole catch is poured into a big ramie or China grass (Boehmeria nives) hang-net hung from small bamboo sticks, fixed in a big fish pond in such a way that two-thirds of the net is submerged in water. Dead fry and extraneous material are removed from the trough by hand or with a dish. For further sorting, sieves are used made of rounded split bamboo about 60 cm in diameter and 25 cm in depth. There are sieves of 20 or more grades for sorting out different species and size groups of fry. The various grades are designated by numbers referring to the fineness of the mesh through which the fry of a certain age and particular species can pass during this final sorting. The fry of undesirable fishes, such as Elopichthys, Siniperca, Luciobrama, are sieved out by No. $2\frac{1}{2}$ or No. 3 sieves. The fry of most extraneous fishes are bigger than those of cultivated species and practically all of them can be strained out with a No. 3 sieve.

After this preliminary sorting, forty to fifty dishes of the fry left in the trough are transferred to a high sorting basket half filled with water. The experts wait about ten minutes and when a large number of tiny brilliant and sparkling eyes appear at the water surface, water from the pond is splashed quickly over the basket. In about half a minute the various kinds of fry will gather together at three or four layers. The explanation of this phenomenon appears to be in differences in oxygen requirements. The silver carp needs ample dissolved oxygen and always comes to the surface when the oxygen content of the water becomes low. The big head requires comparatively less oxygen and for some reason remains in the sub-surface zone. The grass carp requires still less oxygen and the mud carp the least; and these stay in the middle and lower layers respectively. The very tiny Elopichthys and other extraneous fish fry which may remain in the collection will usually occupy the uppermost layer, even above the big head. The extraneous fry are skimmed off and destroyed. The big head and silver carp are skimmed off from the upper layer, the grass carp from the middle and the mud carp from the lower layer and placed in different sections of the basket. The whole work is carried out as quickly as possible taking care to splash adequate quantities of water into the basket, on the sides or in the middle at appropriate intervals in order to oxygenate the water in the basket, lest the fry die for lack of oxygen.

The silver carp and the big head which have yet to be separated are put into partitioned nursery ponds. Most of the silver carp fry liberated in a pond in the morning will have come to the surface by about 4.30 p.m., while the big head remain in the lower layer. A fine-meshed net is then dragged over the surface, not deeper than 5 cm. A part of the silver carp fry stock can thus be collected and kept separately in one compartment of the pond. The remaining fry in the two small compartments are removed the same evening and retained in a long compartment of the pond. This operation is known as first sorting.

The next morning at about 10.30 a.m. the second sorting is done. A fine-meshed net, dragged in the top 50 mm of water, will collect mainly silver carp alone and then when dragged at a depth of 15 cm a mixture of both silver carp and big head is caught, roughly in the proportion 1:1. The remaining fry in the pond will consist solely of big head. While the segregated lots of big heads and silver carp are kept in the long or wide pond compartments. the mixed lot is reared in a wide compartment for about four days. When the fry become bigger, they are fished out and transferred to other wider sections or to larger unpartitioned nursery ponds for further rearing.

Carp Stock in India and Pakistan

The most important stock collected from natural waters in India and Pakistan is the spawn of the major carps, namely catla (Catla catla), rohu (Labeo rohita) mrigal (Cirrhina mrigala) and kalbasu (Labeo calbasu). These species breed during the rainy months, from April to September, depending upon the locality, and the spawn is collected by the spawn 'catchers' as it drifts down the river with the current. In East and West Bengal, Bihar and Orissa larvae and fry are collected; eggs are collected only in the Chittagong area of East Pakistan.

Collecting Eggs. In the Chittagong area fish culturists collect fertilized eggs of carps 12 to 14 hours after they have been spawned. The collection grounds are situated in the sixteen kilometers stretch of the freshwater zone of the Halda River extending from Napitarghat to Ramdas Mushirhat. Since the spawning grounds are very near the tidal zone, the eggs must be collected shortly after spawning, otherwise they may be carried into and destroyed by brackish water.

Spawning generally takes place within about three days before or after the full or new moon, from April to July, with four maxima each season. Collection of eggs is the part-time occupation of the local farmers who, at the beginning of the season, place test nets at suitable places to ascertain the availability of eggs. The test catches enable them to forecast the date of peak spawning when, obviously, most collection is done. The collection gear consists of a simple rectangular sheet of mosquito netting 11 to 12 m long and 2.7 m wide. The net is strengthened with ropes at the margins and at each end a bamboo pole about 2.4 m long is tied. The net is generally operated from a boat by two men, one at the bow and the other in the stern.

The eggs collected are put into a portion of the boat, partitioned off with clay, in which many of them hatch but many more die owing to congestion and lack of proper aeration. A better method is to keep the eggs in nets suspended by bamboo frames in such a way that the river water flows through them. After four to five hours the eggs are transferred to hatching pits; sometimes they are hatched in bamboo baskets lined inside with fine cloth, moored in the river. The embryos are allowed to develop for a few hours but the eggs are transferred to the hatching pits, known as hapas, before hatching takes place. Fry obtained by this last method are believed to be more healthy than others.

The collecting nets are also operated without boats, by men wading in the water, or from poles in the river.

Hatching. The eggs are hatched in the hatching pits dug in the banks of the main river and its feeders. Although the size of the hapa varies considerably, it averages about 5 m x 2.5 m x 0.5 m. The arrangement depends upon the supply of water. They may be in one row, or in two where the row adjacent to the river gets water direct through bamboo pipes or hollowed trunks of betel nut Areca catechu, the other row being fed from the first row.

After the pits are filled with water, mosquito netting is placed over each in such a way that the net sags about 15 cm below the water surface. The rope edging of the net is tied to wooden pegs fixed on the ground at short distances. Bamboo poles parallel to each other are placed breadthwise in the pit below the netting. These poles are rolled regularly with care to agitate the eggs and allow them to come to the surface and thus improve the chances of hatching. Each pit can accommodate about 120 to 300 kg of eggs which may total about 900,000 to 2,200,000. Taking 5 mm as the average diameter of an egg, about 450,000 eggs can be spread in a single layer in a pit of the size generally seen in the Chittagong area. But since larger

quantities are introduced, the eggs lie in several layers in the hatching pit. The larvae hatch out in 6 to 24 hours or more, depending upon the stage of development of the eggs, and pass through the meshes of the netting into the water below. The net may contain membranes of hatched eggs, dead and decomposed eggs, dead and live insect larvae, shrimps, etc., which are removed with the net when all the larvae have hatched out. The carp larvae remain in the pit until the second day, when they are collected with closely woven cloth sheets and transferred into another pit containing fresh water. This procedure is repeated for about a week. Provision of a constant flow of water in the hatchery is said to improve hatching and increase survival. On sunny days, mattings are placed over the hapas on a bamboo framework to provide shade.

This traditional practice is relatively inefficient and when also there is overcrowding the rate of successful hatching is low. Ahmad (1948) therefore suggested improvements and proposed the use of a double, rectangular tank-like structure made of net and fine cloth for each pit, the inner receptacle to be made of net and the outer of cloth. The corners of the inner receptacle to be tied to the corresponding corners of the outer receptacle and the whole device tied to bamboo poles. The material of both receptacles to be kept stretched so that the ova could be spread uniformly. The eggs for hatching to be introduced into the inner receptacle. Hatched larvae, passing through the meshes of the net inner receptacle into the cloth receptacle below would be easy to remove but if a constant flow of water was maintained there would be no need to transfer the larvae from one pit to another, as is now done. Ahmad also suggests that the eggs should not be placed in earthern enclosures in the boats because the water kept in them becomes muddy and must have a deleterious effect on the development of the eggs.

Collecting Fry.* The mainstay of the carp fry industry in India and Pakistan is the fry collected from rivers. The selection of fry collecting localities is based on the empirical knowledge of the fishermen; the principles underlying the selection are not yet known. Generally, collections are made in shallow water near the banks where the current is not strong, and also in small pits and creeks connected with the river. These localities may change from year to year according to the then prevailing topographical conditions. The fry collection season in West Bengal, Orissa and Bihar extends from July to September.

The fry collection gear consists of a funnel-shaped net called Benchi jal in East and West Bengal. It has two lateral wings at the mouth. The meshes of the net are very fine, like that of a fine mosquito net, made of cloth of 12½ counts yarn. The net has two parts, the net proper and the gamcha. The former is 4.5 to 7 m long with its mouth 8 m to 10 m in circumference. The codend is attached to a rattan or bamboo ring 2 m in diameter. The mouth of the net is strengthened by a thin rope. The gamcha is usually shaped like a monk's hood but sometimes has the shape of an open rectangular net. It is connected to the codend and is made of one piece of thin cloth about 1.25 m x 1 m, laced at the end to make a trough.

In shallow inundated banks of the river, where the depth of water varies from 1 m to 3 m, rows of bamboo poles, each consisting of 15 to 25 groups of five poles, are erected and arranged at right angles to the bank and to the direction of the current. One benchi jal is hung from each group of bamboo poles. The mouth of the net is tied to two poles which are placed 2.5 to 3.5 m apart. The middle pair is 4 m to 5 m from the front pair and these poles are placed 18 cm to 20 cm apart. The tail pole is about 1 m from the middle poles. The net is held taut by tying it to these poles. Usually 15 to 25 nets are owned and operated at each center by a group of fishermen, consisting of 7 to 12 persons.

* The term 'fry' is used here to signify hatched fish; at the beginning of the operations many larvae are taken with post-larvae and fry sensu strictu.

The fry, drifting down the river with the current, are caught within the wings and mouth of the net and led into the gamcha where they accumulate. Two fishermen move from net to net in a boat removing the fry every half to one hour or so and never allowing them to crowd in the gamcha. When the fry are being transferred they are gathered into the far end of the gamcha by tilting the anterior part. They are bailed with small bowls and passed through a crude sieve to remove extraneous floating objects, debris, large eggs and the like. The sieve consists of a rectangular, wooden frame with a bottom made of wiremesh or bamboo grill. On an average the catch from one fry net may be about 15 bahtis*. The fry are placed in large earthern basins kept in the boat from which they are transferred to a type of "live well" or "store net" for temporary storage. This is a rectangular receptacle made of very fine cloth, ordinarily 2 m long, 1.25 m deep and 0.5 m high, fixed in the river with bamboo poles in such a way that its upper margin is a few centimeters above water level.

Before the spawn or fry are transported to markets, of which Calcutta is the most important, they are transferred to earthern jars (hundies) of about 36 to 45 liter capacity. Each jar contains 50,000 to 75,000 fry, 4 to 5 mm in size. Generally 75 g to 100 g of special colloidal earth is stirred into each jar, but in Chittagong this practice is not followed as the jars are carried to the nearest railway station slung on bamboo poles. During transport, the water in the jars is kept in constant motion by the jerking movements of the porters. It is especially necessary for the men to agitate the water when the train is waiting at railway stations and at stoppages en route. This movement eliminates the accumulated gaseous carbon dioxide and absorbs oxygen into the water. Special compartments are usually available on the railway for fry. The fry have to be transported about 200 to 300 km to reach the Calcutta market. The headman of the fry-catching team accompanies the consignment. One man can look after 20 to 50 jars during a 10-hour train journey. On arrival at the market the fry are transferred to wide-mouthed earthern pots known as Gamlas, of 70 to 90 liter capacity, filled with unfiltered river water. About 150 to 200 g of colloidal earth is evenly mixed into the water, through a piece of cloth. After waiting for 10 to 15 minutes the dead larvae along with the earth are removed from the bottom by means of a coarse cloth twisted into the form of a rope.

The pH of the colloidal earth used in fry jars generally varies between 8 and 9 and it is believed that the earth is added because of its buffering action. However, Basu (1951) holds the view, based on laboratory experiments conducted by him, that the principal result of adding the earth is to collect the dead fry at the bottom. The earth being colloidal and possessing a positive charge of electricity, the negatively charged dead and floating fry are attracted to the bottom and are thereby separated from the live fry. The dead fry become buried in the earth that settles with them, and organic pollution in the container is thus restricted to the bottom sludge.

At the time of sale the fry are first poured from the storage vessel into a piece of loose-woven cloth. After some water is drained off they are measured with a bahti. Four bahti make a Kunka (a quantity used as trade unit). The fry are bought by owners of nurseries for rearing to fingerlings. Early fry which are thought to come from young parent fish are considered superior to others and fetch a better price.

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* A bahti is a brass vessel fitted with a handle, and may hold from 20,000 to 50,000 larvae.

Sorting Fry. The carp fry collected from the rivers or bundhs may often have among them fry of various undesirable species. Fish culturists and fry traders find it almost impossible to differentiate the fry and identify them below a size of about 3 cm, although some preliminary attempts have been made to evolve a technique of sorting the fry of major carps of India (Alikunhi et al, 1951) following the Chinese technique, the only method that is at present worth recommending, which is to examine the external morphology. Mookerjee, Mazumdar and Das Gupta (1944) prepared the following key for the identification of the fry of the important carps occurring in East and West Bengal waters, by the use of which it may be possible to sort out the various species at the fry stage.

Table for the Identification of the Fry of the Common Carps of Bengal

I. Head conspicuously large from 11.2 mm stage and broad from 17.8 mm stage (No barbels: reddish color of gills visible through transparent opercular flaps)

Catla catla

II. Head of normal size and shape.

A. Three or four black spots on caudal peduncle enclosing a white space. (Lips fringed; color generally grayish; a yellowish spot at the front part of base of dorsal fin and a yellowish band at the nape; barbels black).

Labeo calbasu

B. Spots on caudal peduncle not enclosing a whitish area.

1. Lips fringed.

a. Body marked with longitudinal bands; fins dotted with black.

Labeo gonius

b. Body without longitudinal bands; fins marked with vermilion-red

Labeo rohita

2. Lips entire.

a. A black spot on either side on 5th and 6th scales of the row above lateral line. (Body marked with longitudinal bands).

Labeo bata

b. Black spots absent.

1. A black blotch at base of dorsal. (A second dorsal spot appears at 30.5 mm stage; one pair maxillary barbel noticeable from 14.2 mm stage).

Barbus chola

2. Black blotch at base of dorsal absent.

a. A short, slanting, vertical band, later becoming an oval or round spot, below anterior end of dorsal fin (first ray and anterior margin of dorsal fin black).

Barbus sarana

b. Band or spot below anterior end of dorsal absent.

x. Margins of lips black; minute black dots along lateral line (11.5 mm stage; later forming a longitudinal band).

Cirrhina reba

y. Margin of lips rather whitish; body marked with several longitudinal black bands.

Cirrhina mrigala

Collecting and Conditioning Carp Fry and Fingerlings. Collection of carp fry and fingerlings from natural waters for culture is mainly carried out in Madras State, certain parts of East Bengal, Delhi and Uttar Pradesh. Besides the fry and fingerlings of the Catla catla, the fry and fingerlings of the fringe-lipped carp (Labeo fimbriatus), white carp (Cirrhina cirrhosa), Cauvery carp (Labeo kontius) carnatic carp (Barbus carnaticus) etc., are also collected.

Fingerlings are collected from inundated paddy fields, irrigation channels, tanks, etc., connected with the main rivers. The young fish enter these waters where they are caught by cast nets, drag nets, dip nets or basket traps. The basket traps of Madras State are known as Mavulu and are made of palmyra roots. They are rectangular in shape 1.2 m long, 30.5 cm broad, and 0.9 m to 1.2 m high. On the sides, just above the bottom of the trap, there are holes (about 15 cm in diameter) provided with funnel-shaped structures which permit the entry of fish but prevent their escape. These traps are placed in gaps in the bunds of clay and twigs constructed across the beds of sub-channels and streams expressly to serve as barriers to the movement of young fish. Young fish moving against or with the current enter the traps through the holes in the sides and are caught therein. Square dip nets consisting of small-meshed netting about 1.2 m square tied to two bamboo or cane half-hoops placed crosswise are also used.

Carp fingerlings are captured in the Cauvery delta by regulating the flow of water through irrigation sluices. The fingerlings congregate in large numbers below the sluices and at intervals of about four hours the flow of water is suddenly reduced by closing the sluice gates. Schools of fingerlings get stranded below the sluices and they are scooped up by drag nets or long pieces of cloth. As identification of the fingerlings does not present much difficulty, sorting is easy.

If the ponds are situated nearby, the fingerlings can be carried there in earthern vessels and immediately released. If they must be carried long distances it is necessary to "condition" them since, so it is generally believed, immediately after capture fish are unfit to travel long distances. There is the possibility that the fish will vomit remnants of food and thus pollute the water in the containers. Conditioning is done to prevent such pollution and to accustom the fish to restricted space. The fry and fingerlings are kept for three to seven days without feeding, in special conditioning boxes made of wiremesh, bamboo wicker work, cane and the like, in bamboo livecars, or barrels or boats with perforated bottoms. The period of conditioning depends upon the size of fry or fingerlings and the distance to be covered. Conditioning can also be done in temporary enclosures made of netting or bamboo matting. In East Bengal, shallow portions of the nursery ponds are separated by earth bunds and these are used as conditioning chambers. It would be ideal to condition the fish in the water from which they have been captured. However, the conditioning box should not be fixed in areas with muddy bottoms, since the mud may be stirred up by wading fishermen and harm the fish. When no suitable places are available, the box may be installed on a submerged platform. Shade should be provided and sudden changes of temperature avoided. The optimum temperature in conditioning boxes is believed to range between 26°C and 29°C. (Jagannathan, 1947).

One precaution generally to be observed during conditioning and transference of stock is that the fish should not be handled with bare hands, since by doing so the slime and scales on the body are likely to be removed, making the fish vulnerable to the attacks of fungus and bacteria. Hand nets made of soft cloth are recommended for the purpose. However, it is the experience of many fish culturists that the fish will not be injured in any way if carefully handled. In East Bengal and West Bengal, fry collected from the nurseries are kept in a net in a pond on which water is splashed from all directions. The frightened fry pass excreta and vomit. This has been found to be an efficient method of conditioning. After the fish have been properly conditioned they are ready to be transported. Tinned sheet iron containers are used for the purpose in Madras State.

Stock Collecting in Other Countries

The only freshwater fry collected from natural waters for culture in Thailand are the catfish, Pangasius pangasius.

Fry of Pangasius sutchi, Pangasius micronemus and Pangasius larnaudi are captured in quantities in Cambodia in the Mekong River during September and October. Juvenile fish of the same species, 80 to 150 g in weight, are caught with dip nets from February to April in the Tonlé Sap and in the Grand Lacs. They are shipped in live-well boats to the various fish culture centers for rearing in floating pens and ponds.

In Vietnam Hypophthalmichthys harmandi, Labeo collaris and Mylopharyngodon aethiops are used for cultivation in ponds in association with common carp, or for rough release in confined waters. The three species spawn contemporaneously in the tributaries of the Red River during June. Pond breeding is possible only with common carp, whilst fry of the other cyprinids reared must be collected in open waters.

In Vietnam and Laos, stock of common carp, required for rearing in rice fields, is often obtained by collecting from the rivers aquatic plants to which fish eggs are attached. The eggs are hatched in small ponds or directly in the paddy fields.

In Indonesia, larvae and fry of Puntius javanicus are collected for cultivation from the Bengawan Solo River. In this area about 6,000 ha of milkfish ponds have a salinity so low that they actually have to be operated as freshwater ponds. Therefore fish farmers rear Chanos in association with Puntius or cultivate Puntius alone. The fry to stock the ponds are captured in the lower course of the river where Puntius spawns freely during the west monsoon. The fish deposit the ova on mud banks where creeks or side channels debouch into the main stream. As soon as the first eggs have hatched, fishermen begin to collect the larvae with scoop nets made of fine cloth. Since the spawning period of Puntius covers several months, the catch consists of larvae and fry of various sizes. Other fishes use these spawning places and in consequence the catch consists of a mixture of species. Much experience is required to separate Puntius fry from those of other cyprinids. They can be distinguished by the triangular shape of the head, observable when they are kept swimming in a white bowl or clam shell. Traders often exploit the inability of the fish farmers to judge the quality of Puntius fry and sell badly sorted material containing a large proportion of miscellaneous fishes. After capture Puntius fry are stored in earthern vessels of about 10 liters capacity, filled with turbid river water. Fry more than 20 mm in length are prone to jump in the direction of intruding light until they exhaust and hurt themselves. It is therefore necessary to keep the storage vessels tightly closed. No food is given during storage. Transportation is done in tinned iron containers filled with turbid water which is changed at four-hours intervals. The containers are kept constantly in motion and banana leaves floating on the surface of the

water prevent the fishes from jumping. Physical weakness and a great oxygen consumption make Puntius a difficult fish to transport but Puntius larvae have successfully been carried over long distances in completely darkened open containers. A remarkable shipment was made in 1930 from Java to Celebes where Puntius was used for stocking lakes and swamps.

In Japan and Formosa the young of the eel (Anguilla japonica), 15 cm long and 0.15 gm in weight, are collected by dip nets or bag nets from streams, marshes or from the river itself, when they ascend from the estuaries. Bigger eels weighing 10 g to 30 g are captured with traps or bamboo pipes. The young eels are kept in rearing baskets or boxes for four to five days and then taken to the ponds. Eels are generally carried in special eel baskets; about 3.5 kg to 7 kg of eels can be put into a basket measuring 40 cm in diameter and 20 cm in depth. Five baskets are piled one on top of the other, covered, packed with straw mats and tied with ropes for transport. Ice is placed under the upper cover in hot weather, so that the melted ice drips slowly through the baskets. Fry of Ayu are also collected from the rivers of Japan.

Grey Mullet Collecting and Acclimatizing

Of all the salt water fishes used for culture in fresh waters, grey mullets are probably the most important, and mullet fry are fairly extensively collected in China and India. Shallow coastal waters, estuaries, tidal channels, borrow pits fed by tidal canals, and lagoons are the main fry collection places. The availability period of fry of various species of mullets differs but the collection and acclimatization methods are generally the same.

In China. Chinese fishermen use dip nets for capturing the fry at low tides. The net consists of a rectangular piece of fine-meshed netting of China grass, about 1.5 m long and 0.6 m to 1 m wide, the corners of which are lashed to a framework which is constructed by placing two slats of bamboo crosswise firmly tied and bent over to suit the net. Each slat is about 2.6 m long, 5 cm wide and 12 mm thick. Three sides of the gear are closed by a wall of the same netting 60 cm high, the lower edge of which is laced to the margins of the bottom piece, thus forming a shallow basket of netting open at one side. Generally two fishermen work with two nets laid side by side against the current; the men wade a few meters away closely watching the movement of the fry which, with their feet, they drive into the nets and quickly lift them. Mullet fry is also caught in a 2 m to 4 m square net, made of China grass twine with a mesh of less than 6 mm, fastened to two bamboo poles cross-bent and tied together. The whole device is hung at the junction of the framework to a bamboo pole about 8 m long. The fishermen operate this net from the shore and with the help of the long pole lower it into the water and lift it at will. Generally 25 mm to 45 mm fry are caught and are transferred by a dipper into buckets or kerosine tins of about 23 liter capacity. A mat bag is used for the temporary storage of the fry in water. These fry are stocked directly in the brackish water ponds without preliminary treatment, nursing or rearing.

In India and Pakistan. In West Bengal mullet fry are collected in coastal or estuarine areas where high earth embankments have been built to protect the land and numerous borrow pits have been dug for the construction of the embankments. In addition to these there are shallow creeks, canals, and other bodies of water which can be bunded off easily. The fry are caught with pieces of coarse cloth handled by two men who drag and lift it. A rectangular cloth bag is used for fry collection from the banks of the Hoogly River. A small-meshed circular dip net 50 cm to 60 cm in diameter is also very common. The rim of the net is reinforced with a ring of split bamboo or cane to form a shallow circular bag. In Madras State, South India, mullet fry and fingerlings are collected with fine-meshed drag nets and cast nets. They can easily be sorted out from other salt water fishes but the identification of the various species of

mullet fry is rather difficult. The fry are transported in earthern vessels.

It is generally believed that mullet fry caught from saline or brackishwater areas cannot be stocked in freshwater ponds because the sudden change to freshwater causes mortality. In nature the fry migrate into freshwater and acclimatize naturally but here, of course, there is a slow transitition from saline to freshwater. In the coastal areas of Midnapore District, West Bengal, the fishermen stock freshwater ponds with mullet fry directly after collection from the sea and creeks without any appreciable mortality, there being no long distance to travel. It is still the general opinion that it is desirable to acclimatize and condition mullet fry before transporting them and stocking in ponds. Acclimatization consists mainly in reducing the salinity of the medium in which the fish are kept, by gradual stages, and getting them accustomed to lower salinities and ultimately to freshwater conditions. Experiments conducted in Madras indicate that for mullet fry, 1.5 cm to 4 cm in length, reducing the salinity by 5% at four-hour intervals is satisfactory. (Ganapati and Alikunhi, 1952). The stages and the length of time for process of acclimatization to be carried out depends mainly on the size of the fry and the salinity of the water from which they were caught. The period varies from one to five days, but in certain rare cases this is prolonged to 12 days. Mortality during acclimatization can be minimized by feeding the fish during the process.

Milkfish Collecting and Acclimatizing

In India. The collection of milkfish (Chanos chanos) for culture in fresh water is now an established practice in South India. The first attempt was made in Madras State in 1931-32 and adopted by the extension staff of the Madras Fisheries Department. Fry are collected from sandy regions with gear that consist of a piece of cloth 3 m x 1.2 m and 3 m of rope as a scare-line, with palmyra leaves tied to it at short intervals. Two fishermen hold the ends of the cloth loosely above the surface of ankle-deep water, while another pair drag the scare-line in a semicircle in front of the cloth in such a way that it touches the bottom; this frightens the fry and they leap into the cloth behind. They are transferred by a bowl into a suitable container carried by a fifth man. A drag net may also be used to catch schools of fry from within the area surrounded by the scare-line.

When the fry have to be carried over long distances, they are conditioned in lots of approximately 2,000 for a period of about 24 hours. For transport, 100 to [illegible] fry, depending on their size, are put in a metal carrier of the type used in the Madras Fisheries Department. The cans are filled one-third with sea water and taken to the nearest source of fresh water. About a bucket of water is removed from each can and replaced by an equal amount of fresh water. This process of dilution is repeated three or four times and finally before actually loading the cans into trains, about three buckets of water are drained from the cans and replaced with fresh water, thus making the water in the cans almost completely fresh. The whole process of acclimatization can be done in about six hours.

Experiments conducted by Ranganathan and Ganapati (1949) show that milkfish can be transferred from salt to fresh water directly without any mortality. Although they did not experimentally verify whether the fry thus acclimatized could stand long-distance transport (Ganapati et al., 1950) there is no reason to believe that the ability to travel will be influenced or that they will compare unfavorably with other fry in the matter of survival in ponds.

The fry and fingerlings of other saltwater fishes, such as the pearl spot, cock-up and Indian tarpon, are generally collected with small-meshed drag nets and cast nets. Since the pearl spot has the habit of lying on its side at the bottom and thus escaping the fisherman's net, the "bush method" of fishing them is often used in Madras State. A few small tree branches or plants are tied

together and placed at various spots in the collecting grounds, under which fry and fingerlings take shelter. At intervals of about four to six hours fishermen wade into the water, which is usually 0.9 m to 1.2 m deep, and slowly and carefully drag the bushes to the banks. The bushes are shaken, and the fishes quickly picked out and transferred to suitable containers.

In Indonesia. Milkfish have been used for stocking fresh waters in Indonesia since 1928. Larvae 20 mm long are taken to inland districts, and reared in small ponds, constructed near irrigation reservoirs and freshwater tanks. When the fry have reached fingerling stage they are released to grow in association with the cyprinids (Puntius osteochilus and Cyprinus carpio) which are normally reared in these waters. Milkfish do not form an integral part of the fish population but are stocked solely to make fishing more attractive. They fetch such a high price in the inland areas of Java that the capture of a large fish means a good profit to a fisherman.

In the central provinces of Java, a new system of milkfish culture has come into use since 1952. The larvae are reared in small fry ponds filled with fresh water, or are directly stocked in rearing ponds, filled with diluted sewage water. A high stock density is maintained and the rate of sewage dilution gradually decreased until an abundant growth of planktonic and epithytic Cyanophyceae and diatoms occurs. In this environment the milkfish grow with remarkable speed. The shallow ponds, which usually are less than 2,500 m^2 in extent, are operated on a three-months rotation system. Yields at the rate of 5,000 kg per hectare per annum are no exception. Naturally, the output is lower, but there is no doubt about the high efficiency of the system.

Collection of Stock for Culture in Brackish Water

A main feature of the saltwater fishes cultured in the Indo-Pacific region is that, with the exception of the pearl spot (Etroplus suratensis), none of them breeds in confined waters. The fish farming industry using these fishes must depend entirely on the collection of stock from nature. Brackishwater fish farming is an extensive business in this part of the world and a large fish-fry trade has developed to supply it. The milkfish fry industry is probably the largest and is well developed in Java, the Philippines, Taiwan (Formosa) and Hawaii.

Milkfish Fry Collection and Transport in Indonesia

This industry is concerned with post-larvae and juveniles up to about 2.5 cm in length. The main collection season on the north coast of Java and the coasts of Madura is from September to December with a peak in October/November. There is a second season in April/May. The most suitable places for collection are gently sloping inshore areas with sandy bottoms and clear water. Fry are never caught on clayey beaches. Areas where tidal streams cross the beach, or the leeward side of a ridge of stones jutting into the beach, are ideal for fry collection. There is a definite lunar periodicity in the availability of milkfish fry, the largest catches being made at the full and new moon periods. Collection is usually done during high tides and when the sea is not very rough.

The main collection gear is a triangular scoop net made of coarse fabric, slung on two crossed sticks forming a scissor-like frame. On the north coast of Madura, where there are no lagoons, the fry are directly scooped out of the sea with these nets. Fry are also often caught with scoop nets at ebb tides by fishermen standing in rows across the mouths of creeks. If, in any area, there is no specially suitable fry collection ground, a lure-line, locally known as blabar, is used. It consists of a long palm fiber rope with strips of coconut palm leaves, sugarcane or banana leaves or grasses plaited into it in such a way that long garlands about 10 cm to 20 cm in diameter are formed. These lure-lines are propped up by wooden sticks and set at right angles to the beach so as to float on the surface. The fry take shelter under this

line and are scooped out with the net by a fisherman wading in the water. A slightly different method of operating the lure-line is practised when there are only few fry. About 20 m of the lure-line are paid out in a wide circle at a short distance from the beach. One end of the lure-line is tied to a wooden post fixed on the beach. A fisherman holding the other end of the line wades in the water in diminishing circles until the fry are gathered in a small central space from which they are bailed out with a scoop net. Instead of the lure-line, a low wall of coral rocks is sometimes constructed at right angles to the shore and the fry take shelter along the wall from where they are removed with scoop nets.

The fry are transferred from the nets by means of large shells to earthenware jars, known as belabu or kepeng, containing clean sea water. Sometimes (Botke, 1951) they are directly transferred to jars containing diluted sea water in the proportion of ten parts of fresh water to one of sea water. At this stage the fry are isolated from those of undesirable fishes. Transference to water of low salinity (about 3 ppm.) kills most of the tiny prawn larvae collected with the milkfish fry, but the Chanos larvae acclimatize successfully. It needs a good amount of experience and skill to distinguish the milkfish from the fry and larvae of other fishes. According to Botke (1951) the fishermen distinguish the milkfish "by its eyes, two black spots on the head, its stomach, one black spot in the center of the body, and by its charateristic movements". The fishermen sell the fry directly on the beaches to peddlers or bring them to the storage houses of the fry dealers.

Flat, water-tight bamboo baskets, known as walu, covered on the inner sides with cement or tar are used for the transport of fry. These baskets are made of finely interwoven strips of bamboo; the bottoms are raised slightly in the center. The methods of caring for the fry during transport by rail, road or ship, vary widely among dealers. The baskets are filled with water to about 3 cm above the raised central part. During transport the basket, and the water in it, are in constant motion, giving proper aeration. The number of fry that can be carried in a basket depends largely on the duration of the journey. Generally 20,000 to 40,000 fry go in one basket of 15 liters capacity. When they have to travel in very dilute sea water, the usual proportion being one part of sea water to nine parts of fresh water, the water is changed every other day. When no sea water is available on the journey, unrefined salt, preferably salt collected from ponds during the dry season, is used to obtain the required water salinity, the degree being determined by taste. The fry are fed on rice flour, often slightly roasted, or on finely mashed hard-boiled yolk of egg, on long journeys or when stored in warehouses.

The fry often pass through several hands before they reach the fish farmers. Every time the fry are transferred they are counted, an activity requiring great skill and experience. A few fry are taken with a little water in a white shell or small tea cup against the whiteness of which they are clearly visible. The dealer determines the number of fry in the cup with a quick glance and then transfers the lot to a vessel. Extreme skill is called for in this quick removal of the desired quantity of water with the required number of fry. Sometimes a piece of cloth is spread over the opening of a wide-mouthed jar and pressed and kept in place with a stone below the surface of water to a depth of about 5 cm. The shallow receptacle thus formed by the cloth in the jar facilitates the removal of three to six fry at a time. Numbers are reckoned in terms of radjuts (55), atus (550) and rean (5,500), and counting is often done in terms of number of shells, this being necessary with uneducated workers. From a consignment of 100 or more reans one rean is counted as a sample and the total number of fry in the consignment is then estimated on the basis of the sample, as previously agreed.

The quality of the fry is of great significance in their suitability for intensive culture. Probably the most important point is the time elapsed between their capture and time of stocking. Fry transported over long distances and fed on artificial food, or which have been

stored for more than 20 days, are generally weak and not of high quality. However, a few traders know how to keep fry alive for long periods of time. They put only a few hundred in a vessel and with a special diet keep them alive for over three months. Fry brought from nearby places are considered to be of better quality than those from far-off places. Also, fry caught during the beginning of the season are said to be stronger than those caught at the end. Those caught in September/December are believed to be of the highest quality and therefore the most expensive.

Milkfish Fry Collection and Transport in the Philippines

The milkfish fry industry in the Philippines is of considerable size. It is a seasonal occupation extending from March to August, with a peak in May/June when an immense number of fry are found on the shallow sandy coasts. Four kinds of collecting gears are common in Luzon, namely the fry trap, saplad or saplar; the seine, sayed, sagan or salap, the dip net, panagap, and the scoopnet, sakag.

The saplad or saplar is a V-shaped barricade of crushed bamboo or woven palm leaves partly immersed in water and tied to wooden or bamboo poles which are staked at the bottom of the tidal stream. It is 2 m to 5 m long and 3 m to 5 m wide. At the apex of the V is a gap of about 30 cm which leads into a half-hoop net, made of local cloth, 1.5 m long and 60 cm wide, attached by means of strings to two parallel bamboo poles, pointing downstream. Fishing with this device is done at the mouths of rivers and tidal creeks. It is set in shallow water, about a meter in depth. A number of these may be set all along the entire width of a tidal creek. The fry are led into the net by the V-shaped fencing through the gap during a running tide. Sometimes these devices are automatically adjusted with the rise and fall of the tide.

The sayed is a seine net, 5 m long and 1.3 m wide, made of coarse cloth. It is dragged along the shore by two fishermen holding each one end of the net. The sagan is a rectangular cloth net, 1 m to 5 m long and 1 m wide, so made that it forms a shallow bag at the central portion. Its margins are usually strengthened with coarse cotton twine or fiber rope. It is mounted on two crossed bamboo slats about 3 m long, 5 cm wide and about 1.3 cm thick. While one man can operate a small sagan, two men are required to handle the large ones; fry are collected by dragging the net along sandy shores and margins of river mouths. The net is periodically raised and the catches gathered into its central part by manipulating the handles. The fry are removed with bowls or cups and placed in earthenware containers.

The panagap, also known as salok, is a fine-meshed dip net, mounted on a triangular frame. It has a handle at one point, varies from 0.5 m to 1 m in length and is operated by one man. During the peak of the season good catches are made, especially in narrow tidal streams. The sakag, scoop or scissor net, has a frame of poles only on two sides of the triangle. The poles are so fixed at the point where they meet that the angle can easily be varied. The free side of the net is reinforced with abaca fiber or coarse cotton rope. This scissor net is operated by one man on level and sandy shores.

The fry caught are small, about 10 mm long, very slender and so transparent as to be nearly invisible. Bowls, cups or white enamelled basins are used for moving the fry from the net into wide-mouthed 'pot-bellied' unglazed earthenware jars (paalok or palyok) of 20 to 30 liter capacity, each holding 2,000 to 3,000 fry. To separate the milkfish fry from others, a type of sieve in the form of an open-top cylinder of wire netting, about 1.5 mm square mesh, is used. The bottom is closed either by an abaca fiber cloth or piece of board. The cylinder is partly immersed in a large basin of water and the catches are poured into it from a smaller

basin. The tiny fry of milkfish pass through the sieve but larvae and fry of other fishes are retained. Sorting is also done by taking a few fry at a time from the basin with a clam shell or small dish, and hand-picking.

The method of counting fry in the Philippines is similar to that employed in Indonesia. One man counts the fry in a small bowl or clam shell and when the man calls out the number a corresponding number of pebbles or shell counters are set apart. A thousand fry are first counted, and their density in a basin is used as the basis of comparison for the separation of the rest of the catch into lots of thousands. The average number of fry in, usually, 10 jars are used to determine the total number in a consignment.

Fry is transported in the earthen jars described above, of 15 liters or 30 liters capacity, taking about 100 fry per liter. The salinity of the water in the jar is gradually lowered by dilution to permit easy changing and addition of clean water during transport in inland areas. The jars are covered with pieces of betal-nut palm sheaths or areca-nut palm sheaths. The fry at this stage need very careful handling: small carelessness may result in the loss of the whole lot. The fry are said to be capable of starving for a period of two weeks and usually the transport is arranged so that the consignments reach the destination in about two weeks. Mortality during the journey is 5 to 10%, depending upon the distance covered and the time taken.

Milkfish Fry Collection in Formosa and Hawaii

The season for the collection of milkfish fry in Formosa extends from April to August with the peak in April/May. The sources of fry are the shores, estuaries and bays. Men, women and children engage themselves in this industry. The definite lunar periodicity in the abundance of fry observed in other areas has been noticed in Formosa and the largest catches are obtained at spring tides during the full and new moon periods.

The gear used for the capture of fry are the scoop net and the bag net. The scoop net is triangular in shape and made of China grass. The size of the net varies, mainly depending on whether it is meant to be operated by children or adults. Usually the width at the front is 1.2 m to 1.8 m and the length of the poles varies from 1.5 m to 2.7 m. Two bamboo poles fastened crosswide form a sort of frame and two sides of a triangular piece of net are attached to it. The free ends of the poles serve as control handles. The net is kept afloat by the poles and the framework keeps it in position with the front open. The free side of the triangular netting has a foot line to which lead sinkers are attached. A bamboo or a metal container, fastened to the codend of the net, holds the fry.

The net is operated by wading in shallow water or, if ~~too deep, by~~ swimming with the help of an inflated rubber tube around the waist. The water is scooped and sieved with the net and every 15 or 20 minutes it is raised to gather the catch into the container at the codend. From this container the fry are transferred into buckets for temporary storage. The catch consists of 30 - 100 fry per day.

The bag net, though a costlier gear, is a more efficient device for capturing milkfish fry, especially in deeper water. It is a seine, made of China grass cloth, the mouth of which is kept open by floats and sinkers. There are two long wings and the codend is a 'box' with an opening at the top. In deep waters the net is operated from a bamboo raft, a team of three or four people being needed. One rope tied to the net is held by a man on the raft which is pulled by a man walking along the shore. At regular intervals the dragging is stopped and the catch removed with a dipper. Where there is good current, the net can be anchored, the fry

being carried into it by the current. In very shallow waters two men can drag the net, holding the tips of each wing. The fry are stocked either in buckets or in cement tanks which are constructed on the beach or somewhere nearby. The fry are sold directly to fish farmers, or to dealers who sell them from their shops which are mostly located at Tainan. The fry are carried by men over short distances, like the carp fry, in bamboo baskets slung on bamboo poles. Long-distance transport is done in galvanized iron cans (45.7 cm high and about 33 cm in bottom diameter) which hold about 3,000 fry. During long journeys, mostly in trucks, the water is changed twice by ladling it out with a wooden dipper, through a gauze strainer which is lowered into it, and then fresh water mixed with common salt in the correct proportions is added to the can. The shops keep the fry in cement tanks of about 3 m^2 area, fed with tap water rendered sufficiently saline by the addition of common salt. About 20,000 fry can be stored temporarily in each tank of this type. Care must be taken to protect the fry from sudden cold spells in winter and from heat during summer.

In Hawaii, the ancient method of stocking was merely to allow the fry to enter the ponds through sluice gates with the in-coming tide, and to prevent the exit of the fry by closing the gate. Improved methods have been adopted in recent years, the fry being collected along the shores of the reefs and stocked in the ponds. Screened gates are provided in such ponds so that there is an interchange of water between the pond and the sea and no large fish enter or leave the ponds.

Collection of Mullet Fry

In India and Pakistan mullet culture in brackish water is practised in the estuarine areas of East and West Bengal, where fry of all local species are stocked in ponds.

During winter months, when the estuaries abound with fry of mullets (mostly Mugil parsia), the sluice gates of fish ponds are opened and the fry are allowed to enter with the tide water. Besides this, extra gaps may be dug on the embankments to allow more tide water to pass through. The possibility and desirability of collecting mullet fry from the rivers, swamps, mud flats and tidal creeks, has been suggested but the local fish culturists have not yet adopted this practice.

In the State-owned mullet farms in Cochin (South India) mullet fry are collected from adjoining swamps with fine-meshed pouch or purse nets. These are rectangular in shape, about 12 m by 6 m. The size of the mesh gradually diminshes from 2.5 cm at the mouth to 6 mm at the posterior end. A net is set in shallow water with the mouth kept open by two fishermen standing at the wings, the upper margin buoyed with wooden floats tied about 60 cm apart, and the lower is kept down by the men standing on it. A scare-line, 30 m to 60 m long, with palm leaves strung all over it, is operated in front of the net. As soon as the scare-line is brought near the net, the purse is closed by bringing the two margins together. It is then hauled up, fry and fingerlings are gathered and the catch then transferred to nearby fish ponds.

POND BREEDING

The Common Carp (Cyprinus carpio)

The breeding of common carp in ponds is an industry of great antiquity and the European, or Dubitsch, method is fairly well known. In most countries of the Indo-Pacific region, pond breeding of the common carp is conducted throughout the year, unlike Europe where it is possible only in spring. The methods adopted in the region vary greatly: the most intensive and highly evolved techniques appear to be those employed in Indonesia and Japan. Primitive carp

breeding methods may consist merely of providing some floating vegetation for the attachment of eggs in a common stocking pond. Special ponds, 30 to 40 cm in depth and resembling Dubitsch ponds, are in use in Indonesia. In the mirror carp ponds of India, a thick growth of aquatic vegetation on which the eggs can be deposited is allowed to grow on the pond bottom. In specialized methods separate ponds are maintained for brood fish for spawning, hatching and other purposes.

Brood Fish Pond. Brood fish ponds are maintained at special common carp fry stations in Japan for the supply of fry for culture in rice fields. In other countries the breeders are grown in ordinary stocking ponds and selected breeders are retained in temporary enclosures made of bamboo screens, keeping the males separate from the females. A brood fish pond is generally constructed in an open area, where chilly winds are not likely to blow directly on the pond. Exposure of brood fish to cold is believed to delay spawning. The pond has strong embankments and adequate sluices. A small pond of 100 m^2 area and about 2 m deep can hold 30 to 50 brood carps over 2 kg in weight. The brood fish are fed well with rice bran, kitchen waste, etc., but care is taken to see that they do not grow too quickly.

Spawning Pond. A spawning pond for the carp should be small so that the spawners can reach one another easily. A common and satisfactory spawning pond is rectangular in shape, 16 m^2 to 40 m^2 in area and 0.6 m to 1 m deep. An essential requirement is that it should have a hard bottom, devoid of mud or silt. The bottom is often cemented or covered with sand so that the water in the pond does not become turbid when the spawners chase around. There should be no grass or weeds on the pond bed, lest eggs should be deposted on them instead of on special "collectors" provided for the purpose. If the bottom is hard or stony, the fish might be injured while moving about, but this can be prevented by maintaining a depth of about 50 cm of water near the inlet and about 70 cm near the outlet. Such an arrangement has the added advantage that the pond can be drained easily. If the pond bottom is not sufficiently hard, a marginal trench is dug to permit easy drainage. The water fed into the pond should be fairly clear; if only turbid water is available it should pass through a sedimentation tank before entering the pond. In cold climates care is taken to maintain the pond water at a temperature above 20°C.

In the absence of specially constructed spawning ponds, enclosures in stocking ponds, made of bamboo screens, will serve the purpose, provided suitable pond bed and water conditions are maintained.

An essential arrangement in a spawning pond is the provision of suitable material on which the fish can deposit the spawn. The old practice, prevalent even now in many countries, consisted of spreading plant material such as grass, on the water surface. In China, aquatic plants such as water hyacinth and goldfish weeds (Ceratophyllum and Myriophyllum) are commonly used for the purpose. To keep the weeds together and in place, a square bamboo frame, enclosing an area of about 10 m^2 to 25 m^2 is used. This practice is still prevalent in the area, but instead of ordinary plants, special devices known as kakabans are used in Java, Indonesia. This was evolved to eliminate some of the disadvantages of the old practices. Decay of plants, which is especially liable to happen when mating is delayed, may cause serious loss of eggs. Lack of sufficient surface to attach eggs in such floating "collectors" may also result in loss of eggs. The Sundanese fish farmers in West Java found the horse-hair-like fibers of Indjuk (Arenga pinnata and A. saccharifera) efficient "collectors" for eggs in spawning ponds. Substitutes for this fiber can be found in most countries of the Indo-Pacific region, in the materials used for the manufacture of ropes, brooms and brushes. The Indjuk fiber, used for the preparation of kakabans, is elastic, long, strong, black in color and its strength is increased by soaking in water for about five days. Kakabans are simple devices made by arranging fibers, 50 cm to 70 cm in length, breadthwise and holding them in position by two

bamboo slats 1.5 m to 2 m in length, nailed together on the two sides. In a spawning pond a bamboo pole is placed on the surface, held between two posts fixed at both ends. The kakabans are then laid out close together in such a way that they float on the surface of the pond, supported by the bamboo pole. The carp attach the eggs to the lower surface of the kakabans. The fish farmer inspects the kakabans periodically when the spawning is in progress, and when one side is covered with eggs, the kakaban is turned over, so that more eggs may be attached on the opposite side. When both sides are covered with eggs, the kakaban is replaced by a fresh one. Generally five to eight kakabans are required for every kilogram weight of the spawners. Well prepared kakabans can be used for a period of one or two years.

Hatching Pond. A hatching pond is about 50 m^2 to 100 m^2 in area. In cold climates it is located in places protected from chilly winds and where the maximum amount of sunlight is available. The bottom must be very fertile, and may be muddy. The bottom should slope from 30 cm to 40 cm near the inlet to about 80 cm near the outlet. In Indonesia various arrangements are made in hatching ponds to regulate the water supply. The inlet, in one system, consists of one or more bamboo pipes. The design of the outlet makes cropping easy. A wall is built around the outlet consisting of two lengths of bamboo matting set in semicircles with the inter-space filled with earth. The wall is pierced at different levels with bamboo pipes. In the space enclosed by the semicircular wall and the wall of the pond there is a sieve-basket in which the fry are caught during draining.

Other systems are also used.

Constructing a sump inside the hatching pond is a recent innovation. Such a sump is dug in the middle of the pond, surrounded by bunds about 40 cm high. The eggs attached to vegetation or special devices are placed in the sump to hatch, the advantage being that hatching can take place even before the pond is filled with water, which is a great advantage when water is scarce.

The water in the hatching pond should be maintained at the same temperature as the spawning ponds. However, during very cold spells it may be advisable to suspend hatching operations in ponds and broad shallow wooden tubs, holding about 12 cm of water, can be used instead; the aquatic plants or other objects to which the eggs are attached can be placed in the tubs. The tubs should be exposed to the sun during the day and kept in a warm house at night until the eggs hatch out.

The Sundanese fish farmers transfer the egg-bearing kakabans to a hatching pond. As in the spawning ponds, a bamboo pole is placed horizontally between two vertical posts, but in this case the pole can be moved up and down. The kakabans are spaced 2 cm to 3 cm apart. Parallel to the supporting pole and near the two ends of the kakabans two thin split bamboos, with the inner sides up, are placed and across these are laid sufficient pieces of heavy wood or babana stems of appropriate length to cause the device to sink down and remain about 8 cm below the surface. The change of water level does not affect its position. An area of 30 m^2 to 50 m^2 is needed in the hatching ponds to hatch the eggs on one kakaban and for the satisfactory growth of the larvae, depending on the fertility of the water.

Choice of Breeders. A good deal of practical experience is required by the fish culturists in the choice of breeders. The criteria employed relate to body form, fecundity and age. Fast-growing individuals with high body, comparatively more fleshy (or muscular), are held to be desirable breeders. When a good race of carp of this type has been evolved through selective breeding, a pure stock is kept for use as spawners. According to Lin (1950) fecundity of the common carp is judged by the Chinese fish culturists from the size of the belly during the spawning season. "If the female has a soft and comparatively large belly, it is likely to be

a prolific fish". Although, ordinarily, it is not easy to distinguish the male visually from the female, the older males usually develop some tubercles on the sides of the head and on the pectoral and ventral fins. Extrusion of the genital product will of course identify the sex.

The Chinese select as brood fish females of over 2 kg in weight and 3 to 6 years of age. The males selected are of lesser weight and 2 to 5 years old (Lin, 1950). Young males are selected because they are more active in courting. The Indonesian fish culturists select female fish of at least 1½ but preferably 2 years of age, weighing 1 kg to 2 kg and measuring about 40 cm in length. The males, which reach maturity earlier, must be 1 year, but preferably 1½ years of age, generally about 1 kg in weight and 30 cm in length. Such breeders are induced to spawn once every two or three months for 4 to 6 years. Satisfactory results are obtained when an equal number of females and males is introduced into a spawning pond. The Sundanese carp culturists often employ some variations; a female fish as large as 80 cm may be used, and a number of males may be introduced. But the total of males and females introduced must be the same. It is claimed that satisfactory results are obtained thus. Hofstede and Ardiwinata (1953) list the following criteria considered by the fish culturists in Indonesia in the choice of breeders:

a) the body ought to be soft, not too soft, however, as this indicates the presence of too much fat, which hampers the development of the spawn;

b) the lower side of the belly must be broad and flattened; so to say, the fish must be able to stand on its belly;

c) a relatively great body depth;

d) a relatively broad depth of the caudal peduncle which must also be supple;

e) a small head and a pointed snout;

f) rather large and regularly inserted scales;

g) genital opening placed nearer to the caudal peduncle than usually.

Some farmers believe that the best mark of a good spawner relates to the insertion of the last scale before the genital opening; if a line is drawn from the head along the body to the center of the genital opening it should cross this scale and divide it into two equal parts. The way the fish attach the eggs to the kakabans is also taken into consideration by the fish culturists. When they eject too many eggs at one place so that the eggs are excessively heaped on the "collectors", some farmers promptly remove such fish from the spawning ponds.

Management of Spawning Ponds and Hatchery. An adequate proportion of brood fish ponds, brood fish, spawning ponds, hatching ponds and egg "collectors" must be maintained for the economical management of a carp breeding unit. The area of the fry pond should be nearly 20 times that of the hatching pond. Normally the production of a fry pond can be computed at an approximate rate of 10 to 20 thousand fry per kg weight of spawners. A breeder may take roughly 80 days to recover. The essential requirements for a breeding unit are listed below; smaller or larger units would maintain these proportions.

Segregation	at least two ponds, each having a minimum area of 100 m^2 if they are fertile and adequate additional food can be provided.
Spawning	16 m to 18 m x 3 m to 4 m
Breeders	4 sets of 3 pairs
Hatching	5 m x 20 m
"Collectors"	20 pieces of kakabans or an equal amount of surface for attachment of eggs.

The operations in the breeding unit may be said to start with draining and drying the spawning and hatching ponds. During the dry season it may take three or four days for the pond bottom to become sufficiently dry. The bottom of the spawning pond should be drier than that of the hatching pond and this will usually be so, since the bottom of the former should be hard. If there is no sump the filling of the hatching pond must be started two to three days earlier. The bottom of the hatching pond is then levelled out. The chosen brood fish are kept separately in the brood ponds. The spawning pond and the hatching pond sump are then filled. Generally this is done in the early hours of the morning, and by about 10 a.m. the "collectors" are laid out, and the breeders introduced. They are then fed with an adequate quantity of fine rice bran porridge which should be about 1/20 of the total weight of the breeders. Spawning generally takes place during the night of the same day and may be finished before sunrise. If it does not occur on that day, or even on the next day, a fresh start must be made with a new set of spawners. The most usual handicap to spawning, as well as to hatching, is a sudden change of temperature caused by wind or heavy showers. The fish do not spawn when it is cold, and if they do many of the fertilized eggs may die. In such circumstances special wooden tubs of the type described above are used for hatching the eggs. When kakabans are used as egg collectors, they must be inspected at regular intervals and turned over, if the surface is covered with eggs. As soon as breeding starts the whole hatching pond is filled slowly to prevent disturbing the mud at the bottom. After spawning the egg collectors are, if necessary, washed carefully, with clear water and laid out in the hatching pond or sump which must have a water depth of at least 10 cm to 15 cm. The water in the hatching pond is generally maintained at the same temperature as that of the spawning pond. At a temperature of more than 15°C , the eggs may hatch after six days; at about 20°C in about four and a half days; at about 25°C in about three days. The collectors are, however, kept in the hatching ponds longer than the time appropriate for the temperature, to ensure that all eggs have hatched. If kakabans are used as collectors they are dried in the sun after carefully cleaning and scrubbing the fibers.

The spent breeders remain in the spawning pond itself for about a week and are fed with rice bran or kitchen waste. After a week they are transferred to the hatching pond where they are kept until the pond is drained completely. This is believed to accelerate recovery. Additional food, such as fine rice bran, sufficient to cover one-third to one-half the water surface is provided from the third to the seventh day. From the tenth day after hatching the fry can be collected, small square nets being used for this purpose. In some parts of West Java, coarse rice bran is spread over the hatching pond when the fry are about 10 days old.

For purposes of stocking ponds, the fry are reared to a larger length of 3 cm to 5 cm and about 2 g in weight. This is done in either fry ponds or in paddy fields. In Japan common carp fry are carried in wooden buckets with the water maintained at a low temperature.

Pond Breeding of Major Carps of India and Pakistan. Even though the eggs and fry of the major carps of India and Pakistan are mostly obtained from natural waters, sizeable quantities are raised by pond breeding in West and East Bengal. Experiments in pond breeding of carps have also been conducted in the Punjab. The spawning ponds used for the purpose are known as bunds, which are virtually small reservoirs constructed for the purpose of collecting and storing water. The size of the bunds varies greatly, often they are very large. They are built in natural depressions, valleys, or low-lying paddy fields in which the drainage from an extensive catchment area accumulates. The low end of such a depression is surrounded on three sides by strong embankments, which often are 10 to 25 m long, 5 m wide at the base and 3 m wide at the crest. The pond bed is level, a shallow corner of which forms the spawning ground, known as moan. A thin growth of grass is considered desirable on the spawning ground, as it will hold the soil and prevent the water from becoming muddy when fishermen collect the eggs. In the wet season, the rain water from the catchment areas flows into the bund in streamlets, locally called dhals. In Chittagong (East Pakistan) an earth wall is built in the upland area to collect the rain which then flows into the bund through a gap in the wall. An outlet in the form of a channel is provided on the opposite side of the wall to drain old water. The spawning ground sometimes is situated far away from the outlet and near the inlets. Some bunds have no distinct moan, but the whole pond bed served as spawning ground when inundated. A deep pool, 3,000 m^2 in area with a minimum of 1.5 m of water during the dry season, is the stocking area for brood fishes throughout the year. Fishes are sometimes introduced into this area just before the monsoon season. Bamboo fences protect the mouth of the outlet and prevent the brood fish from escaping. The flow of water through the outlet is controlled by a straw and mud plug. Some fish culturists stock bunds with breeders of the major carps, that is, catla, rohu, mrigal and kalbasu, in the proportion of two males to one female. Bunds, in which the brood fishes are kept throughout the year, are fishes before the monsoon and the number and proportion of sexes estimated; sex ratios are then rectified if there have been any losses. In a bund with embankments about 350 m long and a spawning ground about 6,000 m^2 in area, 200 catla, 100 rohu, 100 mrigal and kalbasu can be stocked. When the water level in the bund increases and inundates the shallow spawning grounds the brood fishes gather there and start chasing. The spawning generally takes place at night and is at the maximum during the full moon and new moon periods. The eggs are collected from the spawning ground by dragging seines of mosquito netting (about 4 m by 1.5 m each) operated by six to eight persons. A large percentage of the eggs is often destroyed by the fishermen's feet. The eggs are transferred into suitable vessels with brass bowls (bahtis) and carried to hatching pits. These pits, or hapas, are dug as near the bunds as possible, and may be 1 m to 1.3 m long, 0.6 m wide and 0.3 m deep. Rows of them are constructed, often in a nearby paddy field, and the water overflowing from the bund is let into the hapas through small canals. Each hapa is filled with water and six bahtis of ova are placed in it. The inlet is then closed and the temperature of the water increases rapidly, thereby reducing the hatching time to 12 to 18 hours. Hatching in lower temperatures may take as long as 36 hours. Hatching is generally complete within 18 to 24 hours after the introduction of the eggs into the hapas. Many of the eggs die in the stagnant water of the hapas from bacterial decay and insufficient aeration. Improvement of the hapas on the lines suggested by Ahmad (1948) or the use of "live wells" can reduce this mortality. Larvae are sold to nurserymen and any left over are reared by the bund owner in fry ponds.

Pond Breeding of Gourami (Osphronemus goramy). Gourami can be bred in confined waters with ease; and this has been one of the main reasons for its introduction into so many of the countries of the Indo-Pacific region. The main requirement for gourami breeding is suitable water plants or other material for the construction and attachment of the nests. In India, and other countries, plants, such as Typha, are planted for the purpose on the margins of ponds where gourami are cultured. No special spawning ponds or breeding methods are used. In the Philippines brood fishes are introduced into large ponds having more than 1.5 m depth of water and a good marginal growth of aquatic weeds.

Specialized breeding of gourami is practised in some districts of West Java, Indonesia, where in the highlands gourami breeding and nilem rearing are generally combined in a common pond. In a "growing" pond, at least 700 m^2, aquatic plants such as Hydrilla verticillata are planted to bind the bottom soil and offer shelter to the fishes. For nesting, branching stems of common bamboo (Bambusa vulgaris) are planted in the pond at distances of about 5 m. According to Hofstede and Ardiwinata (1953) "sticks of non-ramose bamboo, plaited open at the end" can also be used for the purpose, one pole per spawner being provided in the pond. In addition swabs of indjuk (Arenga saccharifera) fiber in between the split ends and small bamboo sticks serve as nest-building material. These are kept submerged to about 20 cm below the surface in a portion of the pond where the depth is at least 70 cm. Five-day-old nilem larvae are stocked first, and a few hours later, the gourami breeders. The age of brood fishes, preferred for pond breeding, differs considerably in various localities. Although gourami is believed to attain maturity when about one and a half years old, four-year-old fish are preferred for the purpose in certain localities, and six- to eight-year-old fish in others. A rounded belly and reddish coloration of the fin rays are considered to be maturity signs. The number of breeders put into a pond is generally at the rate of one female per 100 m^2 to 150 m^2 of water area. Brood fishes are stored in special ponds about 50 cm deep and fed on soft leaves such as those of Colocasia, Carica, Manihot and Ipomea, and on soft fruits and rice bran. Carica and Colocasia leaves are believed to be the best feed for spawners. Such additional fodder is given at the rate of 20 percent of the weight of the breeders every day for a period of about 30 days. The farmers generally introduce breeders into the spawning pond in the proportion of three females to two males. As a very large male may fertilize the eggs of three or four females, some slight adjustment may have to be made in the sex ratio according to the size of fish. Sometimes tawes (Puntius javanicus) is also added to this stock, in which case additional planting of Hydrilla is needed. According to Hofstede and Ardiwinata (1953) the beginning of spawning can be determined by the fishy smell that emanates from the nest and the oily substance that comes to the surface. If the nest is gently pressed with a stick, more of this oily matter may rise to the surface. The eggs hatch out approximately 10 days after the breeders are introduced. A second stocking of nilem (approximately 9 cm long), carp (about 10 cm long), and gourami fry (about 3 cm to 5 cm) is made about 20 days after introducing the breeders. By this time the first-stocked nilem fry and the gourami larvae are strong enough to thrive along with the added stock.

Gourami are also bred solely in special ponds about 100 m^2 in area and 60 cm deep at the inlet and 1 m at the outlet. The pond bed should be muddy and the bank steep. Before filling the pond, nest-building material of the type metioned above is put into the pond. A pond of this size can accommodate ten female and five male breeders. Additional feed is provided in the form of leaves of plants such as Manihot, Colocasia and Carica, at the rate of 10 kg per 30 fish per day and about 4 liters of rice bran twice a week. In about ten days the females build the nests and in another three days spawning takes place and the nests are closed. It is reported that the eggs hatch in about three days. The larvae are fed white ants at the rate of one tea cup per nest, or two cups of peanut waste can be given as a substitute. When the fry are about 1 cm long they are transplanted to a rearing pond, which is four times as large as the spawning pond. In about one and a half months they reach a size of 2 cm. In this way the spawning ponds can be continuously used for the purpose very six weeks or so.

A slight variant of this system is practised in the Pasar Mingu district, south of Djakarta, Java. It aims at shortening the breeding period and makes it possible to breed fresh sets of brood fish at frequent intervals. In this method the nests are taken out of the pond as soon as the eggs are fertilized and the nests closed and transferred to earthenware jars, of about 10 liter capacity, containing water. The nests are opened under the water in the jar, and eggs that are sticking to the sides of the nest are removed along with those floating in the nest.

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Gourami are also bred solely in special ponds about 100 m^2 in area and 60 cm deep at the inlet and 1 m at the outlet. The pond bed should be muddy and the bank steep. Before filling the pond, nest-building material of the type metioned above is put into the pond. A pond of this size can accommodate ten female and five male breeders. Additional feed is provided in the form of leaves of plants such as Manihot, Colocasia and Carica, at the rate of 10 kg per 30 fish per day and about 4 liters of rice bran twice a week. In about ten days the females build the nests and in another three days spawning takes place and the nests are closed. It is reported that the eggs hatch in about three days. The larvae are fed white ants at the rate of one tea cup per nest, or two cups of peanut waste can be given as a substitute. When the fry are about 1 cm long they are transplanted to a rearing pond, which is four times as large as the spawning pond. In about one and a half months they reach a size of 2 cm. In this way the spawning ponds can be continuously used for the purpose very six weeks or so.

A slight variant of this system is practised in the Pasar Mingu district, south of Djakarta, Java. It aims at shortening the breeding period and makes it possible to breed fresh sets of brood fish at frequent intervals. In this method the nests are taken out of the pond as soon as the eggs are fertilized and the nests closed and transferred to earthenware jars, of about 10 liter capacity, containing water. The nests are opened under the water in the jar, and eggs that are sticking to the sides of the nest are removed along with those floating in the nest.

A jar, filled to about 3/4 or 4/5 of its capacity, can hold about 1,000 eggs. One nest may contain 3,000 to 4,000 eggs and so three to four jars are necessary to hold the eggs from one nest. The jars are placed in a shady spot or kept floating in the pond, where they are kept cool. The water in the jars must be changed as often as possible until all the oily substance has been washed off. Thereafter it should be changed once a day if the jars contain 1,000 eggs and twice daily if they hold double that number. This can be facilitated by a fine-meshed sieve in the jar to keep down the eggs and bailing the water out from above the sieve. In two or three days the larvae hatch and float on the surface. They are kept in the jars for nearly eight days during which no food is provided. It is said that the period of their stay in the jars can be prolonged, if necessary, by supplying pond water. Changing the water of a large number of jars is laborious and to speed this work metal containers, in which a continuous flow of water can be maintained, were suggested. The fish farmers of Singaparna in West Java achieved this with a small pond of the type used for hatching nilem eggs in which a continuous flow of water is maintained. The eggs from four nests can be hatched in about 24 m^2 of pond area. The nests are opened and the eggs with the nest material are spread out in the water. Paddy straw scattered on the surface prevents the eggs from sticking together and provides shade. After about ten days the larvae can be collected by drawing the pond water off through a piece of cloth at the outlet. The larvae should then be transferred to a fry pond. 200 m^2 of rearing space may be necessary for the larvae hatched from the eggs of one nest. From the end of the second week, for about three months, nests of white ants are provided as food; fry about 3 cm long can be obtained thus. If the fry must be transported long distances, a size of 5 cm to 8 cm is desirable, and is obtained by rearing in ponds about 16 times the size of the type mentioned above, allowing about 3,200 m^2 for the progeny from one nest. This rearing may take about five months, during which the fry are fed on Azolla pinnata. Minced leaves of various plants can be given as food from the second month onwards.

Pond Breeding of Tilapia (Tilapia mossambica). No special techniques need be adopted to breed Tilapia mossambica in ponds or similar waters, as it is extremely prolific and begins to breed at the age of about two months, when it is about 10 cm long. In fact, it will often be necessary to check the frequency of breeding, because there is a definite lessening or even complete cessation of growth of the female during the breeding period. In a rearing or stocking pond, where an adequate number of males and females are present, they will dig holes and lay eggs on the pond bottom, which should therefore be loose and sandy. A novel method of breeding T. mossambica, practised by a fish farmer in Indonesia, described by Hofstede (1948), is worth following. A spawning pond and fry pond are maintained, the former at a higher level than the latter, in such a way that the water from the spawning pond can flow directly into the fry pond. Breeders are stocked in the spawning pond. When breeding is over and the eggs have hatched, the water from the spawning pond is drained into the fry pond. If the brood fish are disturbed by a net, they will spit out the larvae, which are then carried by the water flow into the fry pond. This procedure is repeated every fortnight and at the end of about one-and-a-half months, T. mossambica fry of three size groups can be cropped from the fry pond.

Pond Breeding of Kissing Gourami (Helostoma temmincki)

In Spawning Ponds. Pond breeding of the kissing gourami is conducted in Indonesia in separate spawning ponds or in freshly harvested paddy fields. Although there are breeding ponds at low altitudes, the most suitable altitudes appear to be 200 m to 700 m above sea level. The spawning ponds are generally situated in quiet and shady spots; they measure about 100 m^2 in area and 50 cm to 80 cm in depth. Smaller ponds of 30 m^2 to 50 m^2 are also used. Special care is taken to strengthen the embankments and prevent all leakage. A good supply of clear water is essential to prevent pollution of water by decaying plankton which must be grown in such ponds. The inlet and outlet of the pond should be fitted with sieves to prevent the escape of eggs.

The pond must be given preliminary treatment before introducing the breeders; the bottom is dried for about a week and then damp paddy straw is spread on selected spots (in small ponds the paddy straw is spread on the whole pond bottom), after which the pond is filled with water. Sometimes the paddy straw is spread after filling the pond. The straw is intended to provide shade to the eggs and to protect the larvae from rain and sun.

Twelve- to eighteen-months-old breeders, roughly 20 cm in length and 150 g in weight, are selected and before introduction into the spawning ponds are held in special segregation ponds, 4 m^2 in area and about 60 cm deep. Forty fish can be kept in each such pond and are given food. Usually the breeders are kept in segregation ponds for a period of 30 to 40 days. One male and one female fish per 30 m^2 to 50 m^2 of water surface are used. Sometimes a greater number of smaller males is introduced, ensuring that the total weight of the males equals that of the females. According to Hofstede and Ardiwinata (1953) the production of fry (about 2 cm in length) of the kissing gourami in various spawnings is as follows:

1st spawning	3,000
2nd "	4,000
3rd "	7,000
4th "	5,000
5th "	2,000

Since Helostoma is a short-lived species, the brood fish can be bred only five times, at intervals of six months. Breeders are stocked when the spawning pond is filled to about two-thirds its capacity; mating takes place in about 18 hours. As early hours of the morning appear to be the best time for spawning, the breeders should be introduced about mid-morning. A characteristic fishy smell is said to be the sign that spawning has started. The larvae hatch out in two days and float on the surface for three or four days; from about the fifth day they can be observed to move into deeper water. By about the seventh to tenth day after hatching, the pond is manured to produce a good growth of plankton for feeding the larvae and fry. The manure usually consists of decaying plants such as Erythrina, Crotalaria, Stachytarpheta, Grewia and Dysoxylum, of which 40 kg to 80 kg are put into a pond. About 20 kg to 40 kg of stable manure can be used instead, and sometimes a mixture of stable manure and decayed plants in the proportion 1:1 is used. Half the total quantity of manure is applied on the eighth day after the eggs have hatched, and thereafter 5 kg to 10 kg every second or third day till the whole quantity is applied. If a more than normal development of micro-organisms follows, decayed plankton may foul the water, and in that case it will be necessary to drain the pond partly and to add fresh water. The color of the water serves as an indicator of the plankton density; it should be bright green. The behavior of the fry also indicates the condition of the pond water: healthy fry move vertically and vigorously upwards to breathe atmospheric air and move similarly downwards. If the fry have been affected by the foulness of the water, they are likely to move slowly. Another method of judging the state of the water is by using fry of common carp. Five hundred to a thousand two-week-old fry, 0.5 cm to 1 cm in length are introduced per 100 m^2 of water area. Abnormal death rate of these fry indicates excessively heavy manuring. This test is made after the first quota of manure is applied.

Sometimes culture of nilem is combined with the breeding of kissing gourami. About 5,000 five-day-old larvae of nilem are stocked after the hatching of the kissing gourami eggs. By the time the fry of the latter are collected, the nilem have attained a length of 2 cm to 3 cm with a survival rate of about 50 percent. When this is done there is no need to use common carp to test the condition of the water.

Fry can be collected from the ponds when they are about a month old. The pond is partially drained and a ditch about 50 cm wide and 10 cm deep, is dug from the supply pipe (inlet) across the pond in the direction of the outlet, leading to a sump or pit 4 m^2 in area. When the pond is drained the fry of kissing gourami (along with carp or nilem) will move into the sump through the ditch. "After that a second and similar sump is dug in the center of the spawning pond. Then a moderate water supply is given through the ditch in which carp or nilem move upstream and are gathered in the second sump while kissing gourami remains in the first one." (Hofstede and Ardiwinata, 1953). The fry are placed in special transport baskets. The few nilem or carp fry mixed with kissing gourami can be separated by stirring the water in the baskets, which will make them come to the surface. They are then easily removed.

The breeding, hatching and rearing operations cover 40 to 50 days before fry 2 cm in length can be obtained. After spawning, the breeders are transferred to stocking ponds to recuperate for the next breeding. A pond, 150 m^2 in area, can hold 75 pairs of breeders. If very favorable conditions exist, and additional food is provided, up to 300 pairs can be stocked. In that case 2.5 kg of rice bran should be provided twice a day. Sometimes the pond is manured with stable dung to provide adequate food for the recovering brood fish. Before the next breeding the sexes are segregated and conditioned for three to seven days in segregation ponds, or in transport containers. A 25-liter container with water to a depth of 15 cm will carry 30 to 40 males or females.

In Paddy Fields. To breed kissing gourami in freshly harvested paddy fields, the bunds must be strengthened so that water can be maintained at a depth of 30 cm. Then the paddy straw is cleared from the field to a distance of one meter from the inner side of the bund. A marginal ditch is dug 20 to 30 cm deep; with the soil removed a second tight bund is built along the inner side of the old one. The breeding techniques are the same as those followed in the spawning ponds. The brood fish spawn between the paddy stalks remaining in the field. Stalk and straw are cut below the surface of the water about seven days after the eggs have hatched. The rearing period of fry lasts from 40 to 50 days. The paddy straw serves as shade and shelter. Water hyacinth can also be used for the purpose.

Pond Breeding of Nilem (Osteochilus hasselti)

Pond breeding of nilem is conducted on an intensive scale in Indonesia in four centers, each using a different method named after the center where it is practised: the Galunggung, the Tarongong, the Wanaradja and the Mage methods. All four centers are in West Java.

(I). In Galunggung the breeding unit consists of a sedimentation tank, a spawning pond, a hatching pond and, sometimes, a special cropping pond. Nilem requires clear, running water for breeding and the sedimentation tank is used to remove the silt from water. From this tank the water flows into a spawning pond (2 m x 2.5 m) with a sloping bottom and a depth of 70 cm near the inlet, and 40 cm near the outlet. At the deepest portion a bamboo pipe is inserted in the bund to render total draining possible. The shallow part of the pond forms the spawning ground and has a growth of grass over it, which binds the soil and is frequented by the fish. The outlet of the spawning pond is provided with gauze and is connected to a hatching pond, 25 m^2 in area, with a sloping bottom, and a depth of 20 cm near the inlet and 40 cm near the outlet. The pond bottom is paved with river stones, over which is spread gravel to a thickness of 1 cm. An essential requirement in a hatching pond is clear water with no trace of turbidity. A big flat stone is placed in the hatching pond, below the inlet, to break the force of the inflowing water and to splash it in all directions. The gravel at the bottom prevents the eggs from sticking to each other. Two outlet pipes are fitted in the bund at the deepest part of the

hatching pond, one at some height to maintain the water level, and the other below the level of the pond bottom to drain it. The larvae pass through the pipes with the water and collect in a square piece of cloth, which is kept partly submerged in the cropping pond. The higher pipe is first opened and when the water level goes down the lower pipe is used.

Before introduction into the spawning pond, the breeders are kept for a week in segregation ponds, about 1 m^2 in area. A strong flow of water is maintained in the pond and the breeders are fed with rice bran, beaten maize or dried manihot. Generally one-year males, about 20 cm in length and 80 g to 100 g in weight, are used. Females, 8 months old, 18 cm long and weighing 50 g to 60 g, may be mature but their fecundity is not high. The most suitable age of spawners for pond breeding is considered to be one to two years. The largest number of eggs are produced at the third spawning when the fish are one-and-a-half to two years old, 25 cm long and 150 g in weight. One set of breeders can be used for breeding every six month, or sometimes even three months. After the fifth spawning the fecundity may be low. Brood fish are seldom used for more than eight spawnings. Equal numbers of males and females are used for breeding. Sometimes some additional food is given. About 50,000 fry weighing 80 g to 100 g each can be expected from three to four pairs of breeders. Some leaves and branches of plants are placed in the pond to provide shade. A couple of hours after introduction of the breeders the water supply is increased so that a strong current of water flows through the pond. Within about two hours after this, breeding may start and by early morning of the second day the spawning should be over. The current of water takes the eggs to the hatching pond where they are spread evenly on the bottom. The water supply is then decreased and direct connection established between the sedimentation tank and the hatching pond, so that a good supply of clear water flows into it. The spawning pond is then drained and the brood fish removed. By the third day the larvae hatch out, and can be cropped from the fifth day onwards; usually the cropping is complete by the seventh day. Within one or two days after cropping the ponds can be prepared for the next breeding. The spawning pond will by then be dry and the gravel from the hatching pond is gathered into heaps and washed with clean water, after which it is again spread out.

(II). In the Tarogong breeding method, a rearing pond is used and a corner of this is prepared for spawning. The ponds vary from 0.5 ha to 5 ha in extent but the common size is no more than 1 ha. Generally, these ponds have a depth of about 30 cm near the inlet and 1 m to 2 m near the outlet. The outlet is placed at the deepest part of the pond to permit complete draining. A drain is fixed above the outlet so that water can be maintained at a fixed level. The spawning ground is generally situated near the outlet and is prepared in the same way as in the Galunggung method. Additional shade, erected on a bamboo scaffolding, is provided and it is believed that the branches of certain trees placed on the scaffolding with the leaves hanging into the water induce spawning. Outside this pond, a hatching pond 5 m x 1 m is constructed in which water is maintained at depth of 5 cm to 10 cm, but if rain threatens to damage the eggs the water level is increased to about 20 cm. The bottom of this pond is prepared in the same manner as in the Galunggung method.

To induce breeding the outlet of the pond is closed and the water level increased. Water is later let into the hatching pond and the necessary current of water produced. The current induces spawning. Nilem breeding is often carried out in combination with the rearing of common carp and gourami. The ponds should be operated to prevent agitation of the bottom mud, and spawners released some time after beginning to fill. Meanwhile the breeders are kept in segregation ponds. About 150 pairs of breeders are put into the pond. Sometimes the same brood fish are used for a second spawning, which is successful in fertile ponds. To do this, half of the water is drained and the pond refilled, so as to maintain a good current. The pond surface is often covered with banana leaves or alang grass (Imperata sp.).

(III). The Wanaradja breeding method is similar to the one practised in Tarogong, but here the fry, when about seven days old, are directly led through a bamboo pipe into a pond about 20 times as large as the hatching pond, where they are reared to small fingerling stage.

(IV). Separate spawning ponds (50 to 60 cm x 25 to 30 cm), which can hold a depth of 30 cm of water, and hatching ponds 2 m to 2.5 m x 1.5 m to 2 m, are maintained for nilem breeding in Mage. The banks of the spawning pond are steep and revetted with wooden planks. The pond is fed from another small pond at a higher level in such a way that the water flows in a strong current. The bottom of the hatching pond is of coarse sand covered by fibers of the Indjuk palm (Arenga saccharifera). The fibers are kept in place by means of bamboo lattice work. The hatching pond is connected with the spawning pond on one side and with a drain on the other. The latter connection is provided with a suitable sieve.

Twenty mature females and ten mature males are stocked in the spawning pond. The breeding may start almost immediately and the eggs are carried to the hatching pond by the current of water, where they are spread and in due course hatched.

Pond Breeding of Sepat Siam (Trichogaster pectoralis)

No special techniques are practised for the pond-breeding of Sepat Siam. The fish spawn in the rearing pond itself; a rich growth of aquatic vegetation, especially Hydrilla verticillata, and a good supply of water rich in oxygen are essential. The females build foam nests in which the eggs are laid. Several broods can be obtained each year. Segregation or conditioning of breeders before introduction into the pond is desirable for spawning.

Pond Breeding of Pearl-Spot (Etroplus suratensis)

The Pearl-Spot will breed in confined waters, both fresh and brackish. Generally no special spawning ponds are maintained, but in ordinary rearing ponds material can be introduced to which breeders will attach their eggs. For this purpose, broad petioles of coconut leaves are kept in pearl-spot ponds in South India. Stone slabs are placed in the form of a platform, to the lower surface of which the breeding fish attach the eggs (slate slabs are preferred in Madras). The hatching of the eggs as well as their later development take place in the common ponds.

In intensive propagation, however, it should be possible to maintain separate spawning ponds where the material necessary for attachment of eggs can be put. The larvae should be removed to separate nursing ponds where they can be reared to fingerlings stage by feeding them appropriate food, such as algae.

Pond Breeding of Tawes (Puntius javanicus)

Tawes is bred in Indonesia successfully up to an altitude of 700 m above sea level, in special spawning ponds 300 m^2 to 500 m^2 area. The breeding operations are best conducted at the beginning of the wet monsoon. Restricted water supply at other times may seriously affect the success of breeding. The most satisfactory depth of a spawning pond for tawes is 35 cm to 50 cm. A strong current of slightly turbid and well-oxygenated water is fed into the pond. The outlet is covered by a sieve-like arrangement. The soil of the pond bottom should be fertile, especially when fry are to be reared for long periods, such as 50 days. Before filling the pond to receive the breeders the pond bed is dried for at least five days. If cracks develop on the bottom, many of the eggs may drop into them and be lost. A silte pond bed is liable to break while a sandy bed will be infertile; so a mixture of sand and sil. is considered the

most suitable soil for the spawning pond. The pond bed is dried to such an extent that a dry crust of 4 cm to 5 cm thick is formed. This drying can be more easily done if the pond is in an unshaded locality. If it is impossible to achieve a dry crust by natural means, dry paddy straw may be burnt on the pond bottom.

The spawning pond is usually filled in the morning and the breeders introduced when it is about half full. Two-year-old fish, about 300 g in weight and about 25 cm in length, are preferred for breeding purposes. Before introduction into the spawn pond the brood fishes are generally conditioned for three to five days. One pair of breeders per 50 m^2 to 70 m^2 of spawning pond area is a good stocking rate in West Java.

During mating, which generally takes place at night, an audible humming noise is produced. If by any chance spawning does not occur as expected, the fishes are induced to do so by beating the water with bamboo slats. If a brood fish is tied by string to a stick in the pond, the splashing noise produced by its movements may also induce spawning of other fish. If these methods do not succeed, the pond is partially drained and, after exposure to the sun during the whole day, refilled. If within two to three days after stocking breeding does not take place, the whole operation will have to be repeated.

After spawning is over the eggs are spread on the pond bottom as evenly as possible and the inflow and outflow of water stopped. The eggs hatch out after two or three days and in about 20 days the fry will be hardy enough to stand a stronger current and then the water flow can be restored. To estimate the density of fry in the pond, a small-meshed net containing fine rice bran porridge is placed on the bottom. After an hour it is rapidly raised and the number of fry collected in the net is considered an index of the density of fry in the pond. Additional food, such as rice bran, is provided in the pond for the spent fish. The quantity that can be consumed in two or three hours is given once or twice a day. A week after spawning the fish are fed on soft leaves of Carica, Colocasia and Manihot. The amount of rice bran in the diet is increased two weeks after the spawning and supplied every second day thereafter. Similarly, the quantity of leaves is increased one month after spawning.

If the pond is not sufficiently fertile, the fry are reared for only 25 days until they measure about 1 cm in length. In fertile ponds they reach a size of 2 cm to 3 cm in about 50 days. Common carp, 10 cm in length, preferably of the golden variety which is supposed to stimulate the propagation of tawes, may be stocked in the ponds at the rate of 15 to 25 fish per 100 m^2. The agitation of the pond bottom caused by the common carp feeding is considered beneficial. The fry are collected at the end of 25 days by sieving the water at the inlet. They can also be collected in a small sump dug just before the inlet. Fifty-day fry have a tendency to swim against the current. To collect the fry, the spawning pond is partly emptied until the fry gather in the central ditch. The water supply is then restored in such a way that the fry can move in the ditch to the inlet. "The fry move upstream to a little pool at the entrance of which a sill creates a small rapid. Instead a marginal trench may be provided, through which the fry move upstream and collect in front of the inlet". (Hofstede and Ardiwinata, 1953). Tawes can breed every four months and the intervals can be shortened to three months if they are given good preliminary treatment. A breeder can spawn a maximum of five times. The males can often be used again for breeding after about 50 days. After breeding, the fish should be removed to segregation ponds, where additional food consisting of rice bran and leaves is given. Excessive feeding should be avoided as it may give rise to development of fat which is not desirable. The average production from spawning units is 10 to 20 thousand fry per spawner when the fry are reared for 25 days, and 5,000 advanced fry per spawner when reared for 50 days.

Another method to breed tawes was developed in East Java to win fry in places where topographical conditions make application of the previously described technique impossible (Schuster, 1952). A spawning pond, 0.1 ha to 0.2 ha in size and 0.6 m deep, is constructed on a suitable site near a streamlet which, due to large catchment area, carries a more than normal quantity during rain squalls. A square pool or pit about 4 m x 4 m and 0.5 m deep is dug in the bottom of the pond. This pit is used to store 20 pairs of breeders which preferably should be stocked at the beginning of the rainy season. The fish should have been conditioned previously in a storage pond by feeding them with rice bran for about 20 days. Initially, only the pit is kept filled with water while the pond itself remains dry. During a heavy fall of rain the spawning pond is connected with the streamlet and turbid flood water is quickly let into it until normal filling level is reached. After the brood fish have spread over the pond, the water is beaten with sticks to induce spawning. Awaiting suitable weather conditions, the brood fish in the pit should be fed with rice bran and Carica or Colocasia leaves every evening. Fry may be transferred to a rearing pond one week after spawning. Although many eggs may die when they are covered by silt a yield of 100,000 fry from a spawning is not exceptional. The pond can be made ready for the next operation immediately after transfer of the fry.

Pond Breeding of Mata Merah (Puntius orphoides)

The fry of mata merah used to be collected from natural waters in West Java; pond breeding methods have been developed in this country only in recent years. The fry can be bred in special spawning ponds, in combination with the kissing gourami, or in freshly harvested paddy fields both of which should have fertile soil. The techniques of breeding the two fishes are very similar. As in the case of the breeding ponds of tawes, mata merah ponds require a good supply of well-oxygenated water. The depth of water must be 40 cm to 60 cm. The pond bottom is well dried for two to four days and then filled, preferably in the early hours of the morning, after which grass, fern leaves, straw or palm fibers are placed in the pond at several selected spots. A pond dried during the east monsoon and possessing a good growth of grass can be used instead.

Mata merah attain maturity at the age of about eight months when they measure 13 cm to 17 cm and weigh 60 g to 85 g. Before being released into the pond, in the early morning, the brood fishes are conditioned for at least two days. Twenty-five pairs of fish are introduced per 700 m^2 of water area with equal numbers of males and females. If kissing gourami breeding is combined with this, 30 pairs of mata merah and 20 pairs of kissing gourami are introduced per 1,400 m^2 of spawning pond area. In the afternoon the fish are fed on rice bran. By about 9 o'clock in the night mating may start, and in the morning of the next day the yellowish eggs can be found attached to the material on the pond bottom, such as stones and vegetable matter but never to a muddy pond bed. The eggs hatch in about two days, and after a week the larvae are fed daily on fine rice bran. The ponds can be manured to increase the supplies of fish food.

If the breeding is conducted in freshly harvested paddy fields, the paddy stalks that remain after harvesting will serve for the attachment of eggs. Thirty pairs of breeders are introduced for every 1,400 m^2 of water surface. Five days after spawning the stalks are cut at the bottom below the water.

Breeding operations take from 30 to 40 days, but it may be necessary to thin the fry stock after about 20 days. The fry are collected in a fine-meshed sieve at the outlet. Before harvesting the crop, all plant material in the ponds is gathered into heaps and the cropping done as for tawes. When reared in combination with kissing gourami it is easy to separate the stocks because the fry of kissing gourami do not move upstream and so get washed down through the outlet.

The breeders are separated from the fry during cropping, stocked in fertile rearing or stocking ponds and fed on rice bran. If well cared for the brood fishes can be bred every three months. Then 25 pairs are bred per 700 m^2 of water area and the larvae reared for 30 to 40 days; the yield will be from six to ten thousand fry, 2 cm to 3 cm long.

When 30 pairs are stocked per 1,400 m^2 in combination with kissing gourami or separately in paddy fields, the yield will be three to five thousand fry.

Pond Breeding of Goldfish (Carassius auratus)

Whilst in most countries goldfish are bred in common rearing ponds, in Japan they are bred in special ponds. Brood fish, more than three years old, are selected for breeding in special concrete spawning tanks. The tank is washed clean and filled with clear water to a depth of about 20 cm. The males and females are kept separately. Water weeds, such as Myriophyllum verticillatum, or twigs of the willow, Salix gymnolopis, are placed in the tank for the fish to lay eggs on. The males and females are then freed and allowed to spawn. Spawning takes place on warm days from the end of April to the beginning of May. Hatching will take place in about a week, at a water temperature of about 20°C. The fry are transported in wooden buckets filled with clean water. They are reared like the common carp.

Pond Breeding of Crucian Carp (Carassius carassius)

The Japanese fish culturists breed Crucian carp in special breeding ponds. Male brood fishes should be more than five years old, 30 cm to 60 cm in length and 2 kg to 4 kg in weight. The female should be more than three years old, 25 cm to 50 cm in length and 0.8 kg to 3 kg in weight. Three males are placed in the spawning pond for every female. Nests made of the water weeds, Myriophyllum verticillatum and M. spicatum, the creeper, Lycopodium clavatum, or the bark of the hemp palm should be placed in the water. At a water temperature of 20°C the eggs are eyed in a few days and hatch three or four days later. The yolk sac is absorbed in a couple of days, and the larvae should then be fed on soya bean juice, yolk of eggs, and water fleas. The larvae of insects, powdered chrysalis, earthworms and wheat flour are also suitable foods. If reared in a pond or paddy field until September to October, they attain a size of 15 cm to 20 cm and weigh 20 g to 70 g. Crucian carp fry are carried in wooden buckets or canvas tanks.

ARTIFICIAL PROPAGATION OF FOOD FISHES

Trouts, salmons, pond smelt and ayu are the main fishes artificially propagated in Japan. The ayu is cultured in Formosa (Taiwan), following the methods used in Japan. Rainbow and brown trout are propagated on a small scale in India, Ceylon and Australia for stocking game waters. As there are several treatises on the propagation of cold water fishes such as salmons and trouts, a detailed account here of the methods of propagation is unnecessary but the salient features of the practices followed in the Indo-Pacific region are briefly mentioned below.

Artificial Propagation of Land-locked Trouts

The spawning season of the trouts (rainbow and brown) in Japan is during winter, from December to March when the water temperature is about 10°C. Artificial fertilization is by the dry method. Eggs of rainbow trout hatch about 40 days after spawning, those of brook trout in about 50 days, and brown trout in 40 to 70 days according to the water temperature. The eyed eggs can be transported four or five days after the eyes appear. A wooden tray, 71 cm x 51 cm x 5 cm, covered with cotton cloth, can hold about 5,000 eggs. Six such trays are placed one

above the other with an extra tray containing crushed ice on top. Wet moss is kept between the trays and the whole consignment is packed on a wooden box in which a 5 cm layer of ice is spread on the bottom. The trays are fixed on rails inside the box in such a way that they do not jolt. The ice and wet moss keep the eggs moist and at a temperature of 4° to 8°C. If there is danger of freezing, the box must be wrapped in a straw mat or insulated with a lining or cork or felt. All the empty spaces between the trays and the box are filled with crushed ice. The boxes, each of which contain about 30,000 eggs, are then shipped to hatcheries.

The larvae are reared in shallow ponds about 1.2 m square, about 0.3 m deep with a layer of pebbles on the bottom. A constant flow of silt-free water is maintained in them and they are covered with wooden shades to keep them in darkness until the fry have reached the stage at which the yolk sacs are absorbed. Thereafter the young, which are about 2.5 cm long, are artificially fed for about 15 days on fresh animal spleen and liver crushed into juice. Earthworms and Gammarus also are suitable foods. Thirty days after yolk absorption, when the young are 3.0 cm long, they are given a diet consisting chiefly of cattle liver (50 percent) and meat or meat powder such as goby (20 percent), other fishes (10 percent) and living chrysallids (20 percent). All ingredients are mashed into fine particles and kneaded to form a soft mass. Trout, about three months old and 5 cm long, have the same food, but the quantity of liver in the diet is decreased to 20 percent and living chrysallids and fish increased to 80 percent. At this stage the fish are active and the food therefore is scattered on the water surface. Subsequently, vegetable foods are added to the diet; up to 15 cm their rations contain 20 percent of flour, rice bran, and greens besides animal foods. Larger fry are given the same diet, but vegetables are increased to 25 percent. The most suitable diet for young trout is considered to be: protein - 60 percent, fat - 25 percent, carbohydrate - 10 percent, minerals - 5 percent, and a sufficient supply of vitamins. The trout fry also feed on living insects lured into the ponds by hanging lamps.

The number of fry that can be reared in a pond depends on their size and the quantity of water available. The following is the standard generally followed:

Body length of fry	Size of pond	Depth of pond	Number of trout
cm	meters	meters	
5 - 7	14 x 3	0.40	10,000
7 - 9	20 x 4	0.65	10,000
9 - 15	30 x 7	1.00	10,000
15 - 20	40 x 10	1.30	10,000
20 - 25	40 x 10	1.30	400
30	40 x 10	1.30	200
40	40 x 10	1.30	100

Since large trout fry are likely to become cannibalistic, it is essential that they be sorted according to size and reared in separate ponds. Great care has to be taken to protect the fry from diseases and enemies. Otters and fish-eating birds can be prevented from gaining access by covering the ponds with wire gauze.

Artificial Propagation of Anadromous Salmons

The brood salmons that ascend the rivers are caught by drag nets, fishing weirs, locally known as urai, and by fence nets stretched across the streams. The captured immature fish are reared in separate ponds until they mature. The eggs, removed from mature females by cutting open the abdomen, are placed in special egg trays. Milt, gathered by gently pressing the

abdomen of the male fish, is poured over the eggs in the trays, which are then mixed with a brush to ensure fertilization. The fertilized eggs are arranged in hatching trays and placed in hatching ponds provided with a constant flow of clear water. At a water temperature of 8°C the eggs become eyed in about 30 days. Special care is taken to prevent fungal attacks.

The fry are reared in special rearing ponds sheltered from sunshine with wooden shades. The yolk sacs are absorbed in three or four days and the fry come to the surface of the pond and swim about in shoals. They are then transplanted into larger rearing ponds where they are kept for some further time more before stocking.

Artificial Propagation of Pond Smelt (Hypomesus olidus)

The spawning season of pond smelt extends from January to March with a peak in February. The brood fishes are caught by drag nets or gill nets and the eggs stripped and fertilized. The fertilized eggs are placed on beds (30 cm x 24 cm) made of bark of hemp palm. They are moistened and covered with moss before packing in boxes for shipment to hatcheries. At the hatcheries the egg-beds along with the eggs are put into hatching tanks built for the purpose in a freshwater pond, swamp or lake. The larvae are released into natural waters.

Artificial Propagation of Landlocked Ayu (Plecoglossus altivelis)

Ayu breeds from September to early October with a peak in September. Brood fish are captured with traps, drag nets, cast nets, and hook and line. The eggs obtained from ripe females are fertilized by the dry method. Fertilized eggs are placed on trays of palm hemp (measuring 36 cm x 24 cm) each of which can hold about 20,000 eggs. When the eggs have become eyed the trays are covered with moss and packed in boxes for shipment. To hatch, the trays are placed in hatching tanks provided with a constant flow of strained water, the supply of which can be regulated. The larvae are planted in natural waters when the yolk sacs have been absorbed. They swim downstream until they reach a lake or the sea, where they grow to fingerling stage. The fingerlings return to the river the following spring, from February to May.

NURSING, REARING AND LONG-DISTANCE TRANSPORT OF FRY AND FINGERLINGS

Principles of Nursing and Rearing

Even though the ecological conditions in a rearing pond may be more favorable for the young fish than in natural waters, the complexity of factors makes it unfeasible to provide optimum requirements for growth and propagation and for full protection from enemies. This is even more evident in the case of extensive waters such as reservoirs, tanks and canals. Further, the food and feeding habits of young fishes are often different from those of the adults and special techniques may, therefore, have to be adopted. This is not often possible in common stocking ponds where associations of different size groups or species are raised. Spawn and fry collected from natural waters may contain extraneous and undesirable species, as it is difficult to distinguish and eliminate them in the early stages of their growth. If all the spawn and fry collected are introduced into a stocking pond without sorting, a large number of extraneous and predatory fishes may gain access and the stocking of the cultivated species in suitable proportions may not be possible. It is therefore essential to rear the young fish to fingerling stage in separate nurseries and rearing ponds before planting them in the stocking ponds.

Nursery ponds are generally small in size. While rearing ponds are larger than nurseries they are smaller than stocking or growing ponds. The small size of nurseries and rearing ponds ensures easy and efficient control of ecological conditions. Control of the water level is easier in small ponds and deterioration of water and soil conditions can be quickly rectified. Protection from external predators, other than birds and insects, can be provided at no great expense with wire netting. The size of ponds preferred varies very much in different countries, depending on climate and the type of fish culture practised, but the main object of all nursery practices is to protect and nourish the young fish.

Nurseries and rearing ponds are relatively shallow. The optimum depth of water varies with the average temperature of the water and the type of fish cultured. It is seldom more than 1.2 m in nurseries and 1.5 m in rearing ponds. Ponds 0.5 to 0.8 m in depth are very common. Fry need warm water for satisfactory growth, and in deep ponds the bottom layers may not be sufficiently warm. Besides, shallow waters promote the growth of blue-green algae and diatoms which form an important food of some of the cultivated fish fry.

Nurseries and rearing ponds should be capable of being drained with ease. Ponds that dry up during certain parts of the year are preferred to perennial ponds for the following reasons: (1) During the fallow period the mud is aerated and mineralized, the production of hydrogen sulphide is interrupted and aerobic destruction of organic matter initiated; (2) fish enemies are easier to control; (3) the application of poisons to control predators resistant to drying, or of manures for increasing fertility is easier; (4) the cultivation of leguminous plants to increase the soil fertility by fixation of atmospheric nitrogen is possible; and (5) the harvesting of the fry is facilitated if a sump is constructed near the outlet of the pond, where the fry will collect at the time of draining and drying.

A high level of fertility is considered essential in nursery and rearing ponds. As the fry feed vigorously during the early stages, the availability of suitable food is one of the most important factors that influence their growth and survival. The natural fertility of ponds must therefore be enhanced by manuring adequately to induce the production of suitable food items. The food produced in the pond can be supplemented with artificial foods.

The basic principles followed in nursing and rearing fry are indicated above. It must, however, be pointed out that detailed techniques have been evolved in various countries to suit the local conditions. While there may be much that can profitably be adopted from the methods followed in other countries, a wholesale copying is not advocated, since the improvement and extension of local methods are likely to yield better results. Nursing and rearing practices have been developed in the culture of only the more important fishes. The methods followed in nursing and rearing warm-water fishes in the various countries of the region are described below. Exhaustive accounts exist of the techniques of rearing the young of cold-water fishes, such as trouts and salmons in the temperate regions, and the methods followed for their rearing in the region are substantially the same. Moreover, the culture of these species is not typical of tropical fish culture, so, in view of its limited economic importance in the region, no reference is made to these techniques in this treatise.

Fry Nursing and Rearing for Culture in Fresh Water

Carp in China

Preparation of Ponds. The fry of the common carp (Cyprinus carpio) and of the species, commonly known as Chinese carps, are raised in nurseries or rearing ponds in China. Ponds of all sizes, ranging from 100 m^2 to 2 ha are used for the purpose, depending on the quantity of fry needed. For example, to rear 2,000,000 fry to a size of 30 to 50 mm, one pond of 100 m^2, two of 200 m^2 and one of 0.5 ha are considered necessary; the fry are transplanted from the smaller to the larger ponds in accordance with a well-considered scheme. In localities like the Swatow area, where few regular nursery ponds are available, paddy fields are used after the bottom is levelled and the banks strengthened and raised to a height of 50 to 70 cm.

Regular nursery ponds may be used as a whole or may be partitioned with bamboo matting into sections measuring about 0.1 to 0.25 ha each. A 40 x 36 m pond will be partitioned into (1) six equal divisions, 15 x 6 m; (2) two long ponds, 20 x 6 m; (3) two wider ponds 20 x 12 m; and (4) a waterway or channel, 36 x 5 m. The partitioned ponds are used for sorting out fry and the unpartitioned for rearing the sorted fry.

The preparation of a nursery pond is started more than a month before the spawning season. Where possible, the pond is fully drained and the bottom thoroughly dried. In low lands or deltaic areas it may not be practicable to drain them completely, but as much of the water as possible is drained off during the dry months. Such ponds will need additional care to control predators as it may not be easy to remove all of them. In the Linghu district of Chekiang the farmers drain the ponds dry with water wheels and hand pumps. Poisons, such as Camellia* seed cake (sometimes mixed with quicklime), powdered croton seed, or derris root, are generally applied in the nurseries. The quantity varies from 50 to 200 kg per hectare depending on the amount of water left in the pond after draining. When the pond is nearly dry, about 60 kg of quicklime per hectare alone will be sufficient to eradicate noxious organisms in the bottom mud. If there is considerable water in the pond about 100 kg of quicklime and 150 kg of tea seed cake are considered necessary. These substances are broken into small bits, dissolved in a little water in a bucket, and poured evenly on the pond bottom. After a few days the pond can be filled with fresh water, taking precautions to prevent the entry of harmful organisms.

*Camellia sinensis is a plant of the tea family. The residue left after oil is pressed from its seeds and made into cakes. The cakes contain 7-8% saponin. This product is an efficient fish poison very commonly used in the mainland of China. It has also a high fertilizer value and can be used in place of soya bean meal or peanut meal. About 180 kg of Camellia seed meal is used for each hectare of pond area.

When derris root or croton seed powder is used, about 15 cm of water should be in the pond to facilitate the application of the poison. Raw derris root is first soaked in water for a few hours, crushed to loosen the tissues, and then juice containing the rotenone wrung out into a bucket of water. The juice is further diluted, poured evenly on the pond water and then well stirred in by dragging a net or screen through the pond. One kilogram of raw derris root is required to treat one hectare of pond surface.

Manuring. After the harmful organisms in the pond are destroyed by poisons, the pond bed is dried for a month or longer, and then the soil is properly levelled. The pond is now filled and manure, consisting of strong-smelling plants*, with or without cow-dung, is applied at the rate of 1,200 to 2,000 kg per hectare. With the decay of this material the water takes on a greenish-brown color which is considered to indicate a good growth of plankton. The undecayed materials are removed from the pond before, or very soon after introducing the fry.

In the absence of odoriferous plants, cow-dung and chemical fertilizer are used. If 7 kg of cow-dung and 1 kg of ammonium nitrate or ammonium sulphate are applied to a pond of about 100 m^2 with an average depth of 0.5 m, a water bloom can be expected to develop in about a week's time. Thereafter manuring will have to be done at regular intervals. In ponds containing big head and silver carp, 100 kg of goatweed per hectare is added once every three days. Mud carp ponds need 1,200 kg of cow-dung per hectare per day, and grass carp ponds 200 kg of goatweed and cow-dung per hectare every four days, to raise the desired quantity of fish food. For a pond bottom deficient in calcium, 50 to 100 kg of cow-dung or 20 to 50 kg of pig-dung and about 10 kg of lime are necessary. Fry about 30 mm in length are favored for culture, and this size is attained in nurseries treated as above in about two to four weeks. To meet the demand and to save space, as many as 500,000 to 600,000 fry are often reared in a nursery pond half a hectare in extent.

Artificial Feeding. For transportation over long distances, vigorous and hardy fry are required. In such circumstances and when the farmers want to rear the fry to a larger size, artificial feeding is resorted to. The young fry are fed on hard-boiled yolk of eggs, ground into a fine paste. The yolk of four eggs is sufficient to feed 10,000 to 30,000 fry under 20 mm in length. The nurserymen of Szechunan, who raise fry in terraced ponds obtaining their supply of water from hill streams, feed the fry in the mornings and evenings with the yolk of six eggs for every 50,000 fry. Sometimes soya bean milk is used, the milk from 300 to 500 g of soya beans being required to feed 50,000 fry.

In the Lingu district of Chekiang, the farmers feed the fry on soya bean milk, evenly applied to the pond in the morning, at noon and in the evening. Milk, from 4 to 5 kg of soya beans, is required to feed about 180,000 fry at every meal. After ten days the fry are given an additional diet of peanut cake powder.

When the grass carp fry are about 50 mm long they are fed on duckweed (Lemna), and when about 100 mm in length on tender grass, rice bran, silkworm pupae and peanut cake.

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*such as goatweed, Agertium conyzoides Linn., Siegsbeckia orientalia Linn., Solanum nigrum Linn.

Control of Growth. In warm climates the fry of grass carp, big head and silver carp grow to 50 mm, 40 mm, and 55 mm in length respectively, even in highly overstocked nurseries. However, experiments have proved that thereafter the growth of fry is arrested if space is restricted. This fact is taken advantage of by the farmers to deliberately retard the growth. But this requires extreme skill, care and experience if the fry are to be kept healthy and vigorous and at the same time stunted in growth. Careless overfeeding or over-manuring of ponds may lead to the depletion of oxygen and large-scale mortality. Underfeeding will lead to malnutrition and starvation and ultimately to excessive mortality.

Skilled nurserymen plant one million grass carp, big head, silver carp and black carp, 40 to 100 mm long, in a pond of one hectare in extent, with a 1.5 m depth of water. Two million mud carp can be stocked in a pond of the same area. The pond should be well prepared in the manner described above. Artificial feeding is started two or three days after planting the fry. The grass carp are given duckweed at the rate of 3% to 5% of their own weight per day, and the other carps are supplied with rice bran, soya bean milk or groundnut cake meal to the extent of 0.5% to 2% of their own weight, depending on the type of food used. In addition, the pond water is manured once every week or fortnight to increase the fertility. Samples of fry are examined at regular intervals. If they still show signs of malnutrition, such as bony appearance, disproportionately large head, slender body and if the gills, mouth cavity or body show signs of parasitic infection, it will be necessary to transplant them into other ponds. If the fry show signs of distress due to lack of oxygen or accumulation of noxious gases, and come to the surface gasping and gulping, fresh clear water must be admitted, and suitable methods, such as agitating the water, applied to aerate the pond and eliminate the noxious gases.

During the rearing period fry are collected with fine-meshed netting or cloth seines as often as needed, say twice a month. The larger fry are either sold or transplanted to other ponds, the smaller fry being put back into the same pond. Different species of fry are stocked in separate ponds where possible, to avoid the need for repeated sorting.

Carp in Malaya

The Chinese carps are the most important cultivated fishes in Malaya, and nursery practices similar to those of China are followed. The nursery ponds commonly used are about 6 x 9 m in size and 45 cm to 60 cm in depth. As newly dug ponds are not considered suitable, only those at least three months old are used. Before the introduction of fry, all harmful animals are killed or removed from the pond and about 60 kg of cow-dung is dug into the bottom. Small quantities of water (about 9 liters) are added at short intervals to the water in the tub in which the fry have been brought to the nursery so that they may acclimatize gradually to the temperature of the pond water. About 2,000 fry 2.5 to 3.5 cm in length are then planted in the pond and fed on wheat flour which is spread on the surface of the water twice daily, in the morning at about 8 a.m. and in the evening at about 5 p.m. An abundant growth of Wolffia is maintained in the pond to serve as food. Many nurserymen raise Wolffia in separate feeder ponds 5 x 10 m and ca. 40 cm deep, in which, initially, some 30 kg of cow-dung and 3 kg of prawn dust are dug into the bottom to fertilize both the soil and the water. After the pond has been filled with water some Wolffia are introduced which grow and multiply rapidly. About 3 kg of cow-dung and 0.3 kg of prawn dust should be added every week thereafter. The Wolffia thus raised in these feeder ponds are regularly collected and used in the nurseries as food for the fry.

By the time the fry reach a length of 5 to 7.5 cm they should be transferred to rearing ponds 15 m square and 60 cm deep. For every nursery pond 6 x 9 m, one such rearing pond is needed. The rearing pond is prepared in the same way as the nursery pond, and duckweed (Lemna) and Wolffia put into it. Saucer-shaped baskets containing artificial food, such as

groundnut cake, are hung from bamboo sticks so as to submerge them in the water to a depth of about 30 cm. Three baskets, which should be filled as often as necessary, are necessary for each pond.

When the fingerlings reach a length of about 12 to 15 cm they are transplanted into ponds of 15 x 30 m and not more than 1 m deep. In each such pond 500 to 600 fingerlings can be reared and maintained either at about the same size for sale to fish culturists or fattened for consumption. On a restricted diet, of grass for the grass carp and some groundnut cake for the other species, they can be kept in a stunted state without any adverse effect on their suitability for later fattening.

Carp in India and Pakistan

Nursing of carp fry is practised in East Pakistan and in the north-eastern part of India. In other parts of India and Pakistan it is mostly fingerlings that are collected for cultural purposes and these are either stocked directly in large stocking ponds or reared for a short period in rearing ponds before stocking.

The fish culturists in India and Pakistan generally use small seasonal ponds as nurseries. Although a pond 2.4 x 3 m in size and 0.9 to 1.5 m deep is recommended as suitable for a nursery, perennial ponds larger than 0.5 ha in extent and holding water to a depth of 1.8 to 3.6 m are often used. In a small number of nursery units, run on modern lines under expert technical supervision, the ponds are first drained to dryness, employing manual labor or diesel pumps. When the pond bottom is thoroughly dry it is ploughed well and a short-season crop of leguminous plants is grown to increase the fertility. When the crop has been harvested, the bottom is ploughed again and levelled. If the pond soil is acid in reaction, lime is added until the pH is brought to 8 or 9. The ponds are manured with cow-dung, stable or kitchen refuse and oil-cake at the rate of 40 to 65 kg of manure and oil-cake per 0.2 hectare. The pond is then filled with rain water or clean water from a nearby source. In certain nursery ponds near Calcutta sewage is used to increase their fertility.

One of the important procedures in the preparation of the ponds is the removal of all predators. This is comparatively easy in ponds that dry up or can be completely drained. Where this is impossible, even repeated fishing may not destroy all predatory fish like the murrels (Ophiocephalus spp.). Recent observations show that, besides the common predatory fishes, many species of weed fishes, of the genera Puntius, Rohtee, Barilius, Ambassis, Oryzias, compete with the carp fry for food and oxygen. There are also several types of predatory insects such as Cybister, Notonecta, Nopa, Ranatra, dragonfly nymphs and earwigs that are harmful to the carp larvae. The common pond frog will eat carp spawn. The impracticability of removing all these predatory and undesirable animals from a large perennial pond and the need to completely drain it before planting fry are therefore obvious. Derris powder applied at the rate of 4 to 6 p.p.m. kills all Indian predatory and weed fishes, besides partially destroying tadpoles, dragonfly nymphs and other aquatic insects. The required quantity of derris powder is mixed with water in a bucket or other container and sprayed on the surface of the water or sprinkled by hand thoroughly stirred to mix the poison. Such small doses of poison only stun the fish so they can be salvaged, if necessary, by transferring them quickly to ponds or cisterns containing fresh water where they will revive. The effect of the poison wears out from a pond in two to eight days depending on the dosage used. Large perennial ponds tend to be slightly acid, and to correct this lime may be applied at the rate of 300 to 500 kg per ha, separately or with derris powder.

For controlling insects, such as the back swimmers (Notonectids), in a pond an emulsion of mustard or coconut oil is effective. The emulsion, made of 56 kg of oil and 18 kg of washing-soap will treat 1 hectare of pond area. It can be applied with a sprayer or poured on the pond surface by hand. A still day should be chosen for spraying, otherwise the film of oil will be blown to one side of the pond. A fence of fine-meshed wire netting about 30 cm high and the top covered with coarse wire netting will prevent ducks, geese and similar fish-eaters from gaining access.

In a nursery pond of 0.4 ha 3,125,000 fry can be reared for 12 to 15 days. The plankton produced as a result of manuring and the natural fertility of the ponds provides the necessary food. It is generally believed that the ideal time for stocking a nursery is when the water has turned bottle-green due to the abundant growth of phytoplankton. Recent studies indicate that the early fry of the major carps of India and Pakistan prefer zooplanktonic organisms as food, so a preponderance of these is therefore to be encouraged. Fresh or semi-dried cow-dung applied at the rate of about 11,200 kg per ha will give rise to a sufficient growth of zooplankton. Small quantities of cow-dung, stable refuse, oil-cake and decaying vegetation can be arranged in a corner of the pond in such a way that it diffuses gradually into the entire pond and induces a good growth of plankton. If this results in pollution of the water, a separate manure pit should be dug which will produce sufficient plankton to be collected and transferred to the nursery pond. If a bloom of phytoplankton develops in the pond it should be controlled by dissolving cow-dung or some other organic matter or dye in the surface water; this will prevent the penetration of light into the deeper waters and thus cause the bloom to die out. Some fish farmers cover the pond surface with the duckweed which serves the same purpose.

The presence of adequate quantities of zooplankton in a nursery can be determined by filtering a known volume of water through a fine-meshed plankton net. Filtering 50 liters of water should give a sediment of 0.8 to 1.3 cm in a glass tube of 2.5 cm in diameter when a few drops of formalin are added. If the sediment has a more or less brownish color there is sufficient food for the fry in the pond. Fry in good condition rise to the surface regularly every morning and swim just below it, going down after the sun is well up. The absence of this behavior pattern indicates something wrong with the environment. The presence of predators in the pond, the absence of sufficient food or the fouling of the water are possibilities that should be immediately investigated and the necessary action taken; predators captured, water aerated, food supplied by transferring the fry to another pond. Repeated transplantation, if carefully done without injuring the fry, is considered conducive to their vigorous growth. Artificial feeding enhances their growth and survival. Fry, fed on oil-cakes in quantities not exceeding the following, grow very satisfactorily:

1st five-days period after stocking	-	artificial food equal in weight to that of fry stocked.
2nd " " " " "	-	twice the weight of fry at the time of stocking.
3rd " " " " "	-	three times the weight of fry at the time of stocking.

A fry about 6 mm long weighs about 0.0014 g and a bowl, 7.6 cm in diameter and 3.2 cm in depth, will hold about 30,000 fry of this size. The quantity of artificial food to be given for every bowl of carp fry has been estimated to be: 4 bowls of rice bran or coconut oil-cake; 3 bowls of mustard oil-cake (higher quantities may be toxic to the fry); and $2\frac{1}{2}$ bowls of groundnut oil-cake. The oil-cake should be given in a finely powdered form.

It is advantageous to remove the fry to rearing ponds after about 15 days when they have grown to about 35 mm in length. Fine-meshed cotton drag nets, 0.9 x 1.8 m in size with 13 mm bar mesh, and wooden floats are used for collecting the fry. A nursery pond can be used to rear several lots of fry in a season.

Rearing ponds should, as far as possible, be prepared in the same way as the nursery ponds.

Fry are stocked in rearing ponds at the rate of 250,000 to 500,000 per hectare of pond area. When they have grown to fingerling stage (130 to 155 mm) they are transferred to still larger stocking ponds.

Eel Nurseries in Japan

Eel nurseries in Japan are located in the coastal areas, close to the source of elvers and to fish markets. The ponds are small, the largest being about 200 m^2 in area. Elvers about 68 mm long, weighing nearly 160 mg each, are planted at the rate of nearly 300,000 per ha in February and March. They are fed daily on dried sardines, sardine meal and sometimes silkworm pupae. After a period of three months the population is thinned and distributed into other ponds, each of about 600 m^2. By November the eels have attained an average size of about 15.6 g when they can be transferred to stocking ponds or other suitable waters.

Rearing Salt-Water Fry

The general principles of construction and maintenance of brackishwater fish nurseries are essentially the same as those relating to freshwater nurseries. The main consideration in brackishwater nursery practices is to have fairly small ponds which can be more easily controlled. Very small ponds are, however, avoided, as they are expensive to build and maintain and much space is taken up by the dikes. Fertile soil devoid of organic debris deposits is most favored for brackishwater nursery pond sites.

The saltwater fishes most commonly used for culture in brackish waters on a commercial scale are milkfish and mullet.

Mullet

Mullet fry collected from natural waters are generally hardy and in an advanced stage of growth. Probably because of this, and because mullet culture methods are not yet highly developed, no specialized mullet nurseries are maintained in the region. In some of the brackishwater ponds (bheris) near Calcutta, young mullets are transferred to small storage ponds at the time of annual fishing and then let back into the stocking pond during the following season. Apart from this there is hardly any nursing or rearing practised by the fish farmers. Brackishwater mullet farms are usually situated in the vicinity of fry-collection centers so the transport of fry over long distances is therefore not usually necessary.

Milkfish

As the milkfish fry collected from natural waters are delicate post larvae, 10 mm to 13 mm in size, they are unsuitable for stocking in large ponds where suitable physico-chemical conditions, protection from predators and adequate food may not be available for their survival and growth. It is therefore essential to maintain nurseries.

Practices in the Philippines. Nursing and rearing practices for milkfish have been the subject of fairly intensive studies in the Philippines in recent years and much information has been obtained which will be useful in improving nurseries and rearing units. Besides the nurseries that are maintained as parts of milkfish farms, there are very often separate units, maintained solely to raise and supply fingerlings to the farmers.

Preparation of Nursery Ponds. The preparation of nurseries for a fresh lot of fry starts about two months in advance of planting. All the old stock of fry or fingerlings is removed and the pond drained at low tide. Before the pond bottom becomes completely dried and hardened it is tilled to destroy undesirable weeds and to bring fresh soil to the surface; this also helps in the eradication of predators. The soil is then levelled with wooden rakes in such a way that the pond bottom slopes very gradually towards the outlets. Some farmers dig a diagonal ditch leading to the outlet gate, which serves as a refuge for fingerlings on hot days as well as during cropping. However, if proper care is not taken, fish enemies might take refuge in these ditches and cause damage to the fry. The continued retention of water in the pond often causes an increase in the salinity; sometimes crystallization of salt along the banks can be noticed. This excess salt should be flushed away before planting the fry and fresh, well-oxygenated, clear tidal water taken in. Renewal of pond water is repeated at frequent intervals.

Probably the most important treatment of a nursery pond in the Philippines consists of the repeated draining and drying of the pond bottom. It is allowed to dry for two or three days before water is let in. This is repeated several times. Predatory fishes, such as the murenas and eels that burrow into the mud, are thus induced to come to the surface; snails and other organisms which check the growth of natural food of young milkfish are killed and other fish enemies and competitors eradicated; productivity of the soil is increased by hastening the decomposition of organic matter; and it is likely that the activities of nitrogen fixing algae, bacteria and other agencies are accelerated. Any leaks or seepage in the embankments are stopped and all macro-vegetation growing on the margins of the embankments is cleared. Leakage or excessive seepage is detected by completely filling the nursery ponds with water at high tides, leaving the other ponds dry, or by filling the other ponds and keeping the nursery ponds dry.

When all defects of the embankments are rectified and the pond has been sufficiently dried, water is let in at high tide to a depth of 3 or 5 cm, so as to cover the entire bottom. The gates and pipes are protected with screens made of fine split bamboo and covered with abaca fiber cloth or sinamay. The projecting ends of cylindrical pipes are closed by means of elongate traps made of split bamboo, known as galao. Before planting the fry and during the early nursing stages, the galao are covered with abaca fiber cloth.

Within three to seven days after filling the pond, the growth of a brownish, greenish or yellowish layer of micro-organisms, known locally as lab-lab, becomes noticeable on the pond bed. Shallow water is of extreme importance in the growth of this layer, consisting mainly of algae. As the growth becomes denser it is necessary to increase the water level gradually. The pond water is renewed once or twice a week during this period, taking precautions not to produce a strong current which might agitate the pond bottom.

Bacteria, unicellular and filamentous blue-green algae (Myxophyceae) especially Oscillatoriaceae, fragments of filamentous green algae and diatoms are the floral elements of lab-lab, the animal forms being protozoans, entomostracan crustaceans (copepods and ostracods) free-living flat worms, round worms, and larval forms of molluscs and larger crustaceans. An abundant growth of this complex is essential in the nurseries and the provision of suitable conditions for its proper growth is therefore of great importance. These conditions are:

(i) Fertile soil, clay, clay-loam or sandy clay in preference to sandy or rocky soil. Soils showing a high solution loss and a high content of clay, nitrogen and organic matter are very productive.

(ii) Exposure of pond bed to heat and intense light.

(iii) Low level of water, which may be raised up to 10 to 20 cm gradually with the increase in density of lab-lab growth. Very deep water might cause the growth of filamentous green algae.

(iv) Stagnant clear water of salinity ranging between 10 p.p.m. and 40 p.p.m. Turbidity might check the growth of lab-lab. Mangroves and other large plants around the ponds serve as windbreaks and thus prevent waves and the consequent stirring of the pond bottom which causes turbidity. Very high concentrations of salt, as also salinities of less than 10 p.p.m. are not conducive to a good growth of lab-lab.

(v) Regular renewal of the pond water with clear well-oxygenated water, which will bring in fresh supplies of nutrients.

(vi) Absence of browsing animals such as snails, shrimps, crabs, and bottom feeding fishes.

Lab-lab often gets dislodged from the bottom and floats at the surface or along the margins. This occurs as a result of the accumulation of oxygen within the membranous sheaths of algal plants, and is especially evident when there is an over-abundant growth or when the soil is very loose. Since these masses might endanger the fry, they should be controlled, by draining the pond so that they settle down and get attached to the bottom or, if this is not possible, the patches can be broken up mechanically to minimize the danger. A sudden overgrowth of lab-lab may lead to an ecological unbalance and fouling of the water due to their decay. Overstocking and frequent freshening are recommended under such circumstances. Profuse growths can be gathered and dried, to be used later as additional food for the fingerlings.

Planting Fry. Fry are generally planted in the cooler hours of the morning or evening. It is advisable to equalise the temperature and salinity of the pond water and the water in the fry containers before the fry are planted. The containers are kept for some time partly immersed in the pond, then tilted to allow some pond water to flow into them gently. This is repeated as many times as necessary, depending on the differences of temperature and salinity between the pond water and the water in the container. When a container is almost full it is slowly raised and tilted in such a manner that the fry can swim into the pond with the minimum of agitation. Fry are sometimes planted directly from the sieving box after they are sorted.

The number of fry planted in a nursery is determined by the food and space available. One hectare of nursery pond with a good growth of lab-lab can be stocked at the rate of 30 to 50 fry per square meter. This number is exceeded to produce a reserve of stunted fry for use in stocking ponds throughout the year. While extreme overstocking may result in large-scale mortality, understocking can cause larger variations in the size of fingerlings.

Care of Nursery Ponds. A proper check of the water condition is very important in the maintenance of the nurseries. The pond water may get polluted by (1) accumulations of organic mud on the bottom or from dead planktonic and epiphytic organisms in the water; (2) an excess of artificial food; (3) external polluted water. Mortality due to pollution can be avoided by renewing or diluting the pond with fresh tidal water. It is desirable always to keep a reserve of fresh tidal water for this purpose in separate reservoir ponds or in the rearing ponds. During adverse weather conditions it is necessary to keep the depth of pond water high, so as to avert sudden changes of salinity and temperature. The first three or four days after planting in nurseries are the most critical period for the fry. Heavy rainfall may suddenly lower the surface temperature while the bottom layer remains warm, causing as much as 80% of the fry to die.

Lack of sufficient food is one of the main reasons for mortality or unsatisfactory growth of fish. Poor growth of lab-lab or overstocking may give rise to this condition. Starvation of fry and fingerlings can often be detected by the abnormally large head and the rather compressed tail and trunk; by a shiny lustre at the bases of the fins and sometimes a deep blackish color on the back. Starved fish will not be very active and they fall easy victims to diseases. When the food resources in a nursery get low it is usual to let the fish into an adjacent pond reserved for the purpose, by cutting open the embankment. If the food in that pond is also being exhausted, a partial thinning of stock is necessary. Artificial feeding is another efficient means of remedying the situation. Dried lab-lab or lumut (filamentous green algae) can be supplied. Submerged plants, such as Ruppia, Thalassia, Halophila and Najas (known as digman) grow in ponds where fresh water has easy access. These plants, if gathered and kept in a protected spot to decay, are good food for fingerlings. Very fine rice bran is extensively used in the Philippines as an artificial food for milkfish fingerlings. It is spread twice a day, in the morning and afternoon, at the rate of about 5 to 12 kg per hectare of nurseries holding about 300,00 fingerlings. Feeding with rice bran is common in nurseries where the fingerlings are kept stunted.

Notwithstanding all the efforts made at the beginning of the nursery operations to eliminate predators, they may gain access into the ponds later, along with the fry or through the gates with the incoming tide. During early stages of cultivation they lurk in the vicinity of the gates, from where, with fine-meshed scoop nets, it may be possible to remove many of them. Frogs eggs laid along the edges of the ponds are also removed. Bird predators are shot down or scared away by laying lines of strings above the pond, tied to bamboo poles erected at regular intervals.

Milkfish fry and fingerlings are comparatively free from parasites. Fin rot and external infestation by flat-worms and crustacean parasites have been reported, but these are of very rare occurrence.

Egg cases of annelids and growths of filamentous algae, if present in the pond, may cause mortality by entangling the fry. Larger vegetation may restrict the space and extraneous fishes that gain access into the pond may become competitors for food. Crabs, prawns and shrimps, if present in the pond, may stir up the pond bottom, making the water turbid and thus preventing the growth of lab-lab, and the young of Penaeus prawns may cause mortality when their sharp rostrums pierce the delicate fry. It is, therefore, essential to exclude all these undesirable elements from the nursery ponds.

Stunting of Fry. Although the growth of fry in nurseries is ordinarily very rapid, it varies widely with the availability of food and the density of population in the pond. During the first four to six weeks fry attain a size of 5 to 10 cm in length and 1.2 to 5.0 g in weight. This stage can be maintained for several weeks or months with only a slight increase in size, by overstocking and supplying only sufficient food to keep them healthy.

Transplantation to Rearing Ponds. The minimum nursing period of milkfish fry is about six weeks, after which they can be transplanted into rearing ponds in the farm or sold to other farmers. Fingerlings are transplanted into rearing ponds prepared in the same way as the nursery ponds, but with 15 to 25 cm of water. Both lab-lab and lumut are grown in these ponds, although the early fry are too small to feed on lumut. Both lab-lab and lumut can be produced in the same pond by regulating the depth of water. The number of fish put into a rearing pond is much less than in the nursery ponds. The fingerlings begin to feed on lumut and when from 10 to 20 cm in length, they are transferred to stocking ponds in which they are grown to marketable size.

The fingerlings are collected from the nurseries by taking advantage of their habit of swimming against the current. If only a portion of the crop has to be removed, the pond is emptied during low tide to facilitate collection in a ditch or sump and to expose them to heat during the day. At the next high tide, water is allowed to enter the pond in a gentle flow. The fingerlings, swimming against the current, congregate in the catching pond, which is then closed. They are fished out with fine-meshed seines (panagap). If the whole crop has to be removed the nursery pond is drained until all the pond except the ditches and the catching pond are exposed. The fingerlings congregate in these areas and the gate is closed. Water stored in a special reservoir is then run into the ponds to prevent mortality, and the fingerlings are fished out with seine nets from which they are transferred, in pails, to a fine-meshed rectangular net, known as bitinan, suspended in a canal or pond from four bamboo poles in such a way as to keep the middle portion immersed. The fingerlings are counted in this net. The entire stock, after being gathered into a part of the net, is divided into suitable equal lots by placing bamboo poles crosswise. One lot is counted by scooping out the fingerlings with a bowl or cup, and then the total number in the net is estimated from this count.

Practices in Indonesia. Milkfish nurseries in Indonesia consist of suitable sections of stocking ponds, with a surface area of about 100 to 1,000 m^2, which can be easily drained and kept free from predators, etc. Sometimes special enclosures, measuring 1.6 x 1.8 m with low earthen embankments, are constructed to serve as "baby-boxes" for the fry during the first 24 hours after planting in the ponds. In Central Java, well laid out nursery ponds are not maintained, but instead, the central areas of stocking ponds are enclosed by low earth walls to serve as nurseries. Previously, little attention was paid by fish farmers to the nature of the pond bottom and the water. If the bottom contains much organic matter, anaerobic decay may give rise to the formation of hydrogen sulphide and depletion of oxygen, causing large-scale mortality of fry. The fisheries extension service instructed the farmers to drain nursery ponds and keep them dry for a week or more. This is often done now and the pond bed loosened and levelled by tilling and raking. Foul soil, with traces of hydrogen sulphide, remaining in wet parts of the pond is treated with lime. A thick growth of green algae is considered to be undesirable because the water may be fouled by decaying algae. Clear water is therefore preferred in nurseries.

All harmful animals are generally removed from the pond before it is filled. If the fry, which are often transported to the nurseries in water of low salinity, are put into a nursery pond containing water of high salinity, considerable mortality may occur. Water of salinity higher than 40 ppm is dangerous to fry; the best results are achieved when the salt content varies from 10 to 32 ppm. The time and method of planting are generally the same as in the Philippines. Up to 55,000 fry can be planted in a nursery pond of about 1,000 m^2. Large palm leaves are inserted in the embankments to protect the fry from the heat of the sun. In Indonesia the pond water is generally renewed twice a month during high tides.

The fish culturist regularly examines the water in nursery ponds for the presence of adequate quantities of food, and as soon as a shortage is observed the fry are let into the rearing pond. They are usually kept in the nursery for a period of about 30 days in which time they reach a length of 5 to 7 cm and a weight of 1.4 to 3.7 g. The rearing ponds, about 0.4 to 0.8 ha in size, are also sections of the stocking ponds with level bottoms and devoid of perennial vegetation. High salinity in shore ponds, due to evaporation during long periods of low tides, and decay of organic matter in inland ponds, are the two common causes of mortality during nursing and rearing, which should be detected and remedied in proper time if the survival rate is to be maintained at a fairly high level. Ordinarily, only a 30% survival is expected by the fish farmer in Indonesia but some Chinese fish culturists in the country, who specialise in the nursing and rearing of milkfish fry for supplying pond owners, obtain a survival of 60% to 80% by special feeding methods and proper care. An adequate supply of fingerlings permits the raising of three crops of milkfish a year in the ponds (tambaks) of Java.

Practices in Formosa (Taiwan). Milkfish nurseries in Taiwan consist of small rectangular ponds, 100 to 200 square meters in area, and holding about 30 cm of water. The preliminary treatment of ponds before the introduction of fry is almost the same in nurseries as in stocking ponds. By about November the pond bottom is levelled and all necessary repairs or improvements to the embankments, sluices, etc., effected. The pond bed is allowed to dry in the sun for a period of about two weeks until cracks appear on the top layer. Water is then left into the pond to a depth of 7.6 cm to 12.7 cm and allowed to evaporate until the bottom becomes dry. In February the pond bed is manured with rice bran. Bags of rice bran, each containing 22 to 27 kg are stacked at approximately equidistant spots, then a depth of 7 to 13 cm of sea water is admitted. After one or two days the bran from the bags is spread out as evenly as possible on the bottom. Sometimes straw, grass and sugar cane leaves are also used as manure. The water is then allowed to dry off completely and the pond remains in this condition until March when more rice bran is added to the pond bottom. Sometimes night soil is used instead of rice bran or is mixed with it before application. The same volume of water is let in again. After five to seven days more sea water is let into the pond, raising the level to about 12 to 18 cm. Camellia seed cakes broken into small pieces are then cast into the water at various spots, to kill any extraneous fishes that may have gained access. About ten days, to allow the water to become innocuous, should elapse before the fry are planted. The ponds are now filled to a depth of 18 cm to 20 cm. All these preliminary preparations are completed by the end of March when a profuse growth of algae will have developed. About 800 kg of rice bran is required to fertilize each hectare of pond. Soya bean cake, or night soil is applied at the rate of about 400 kg per hectare. The fry from the nursery ponds are let into the stocking ponds when they reach the fingerling stage. Care is taken to maintain the correct salinity in the ponds.

It is the usual practice in Taiwan to raise two crops of milkfish and for this purpose fry are planted first in March, then in April/May and again in June. While for the last two plantings, new fry, captured during the same season, are used, stocking in March is done with fry reared in special wintering ponds. In Taiwan, the temperature may drop as low as 2 to 4°C, and the milkfish are sensitive to such low temperatures. Unless protected from cold, large-scale mortality may occur. It is essential to preserve the fry during winter because the late fry, planted in June, do not reach marketable size by October, when harvesting is done. These fry are used for the first planting in the following March before supplies of new fry become available. The special wintering ponds consist of ditches 0.9 to 1.2 m in depth, protected by windbreaks constructed of bamboo frames thatched with straw or reeds, slanting at an angle of about 30° towards the pond on the north-eastern side. As the winter is the dry season in South Taiwan, the salinity of the water may often increase due to evaporation, necessitating the addition of fresh water. The fish are introduced in October and kept there until March, feeding them with rice bran on warmer days. On very cold days the fish do not appear to feed. By March the fingerlings will measure 6 to 12 cm in length.

Transport of Fish Fry

When fry have to be transported to far-off places the equipment and methods used for short journeys may not be satisfactory. While the eyed ova of cold water fishes, such as the trouts, can be transported in ice over long distances, warm water fishes are generally transported in the fry stage.

Theoretical Considerations

The basic physiological requirements of the spawn and fry have to be fully considered. In spite of its importance, detailed studies of this aspect have not yet been undertaken. Preliminary work conducted in India and Indonesia has yielded some interesting data and indicated the lines for future investigations. The main requirement in transporting fry is adequate quantities of oxygen. The dissolved oxygen in the water is used up and carbon dioxide is given out. Recent studies indicate that the fry may die in large numbers not only when the oxygen content is low, but also when the carbon dioxide content increases. Even when the oxygen level is much above the minimum requirement, the fry may die if the carbon dioxide concentration is high. Experimental work done in Canada on goldfish has demonstrated a reduced ability to extract oxygen at lower temperature in the presence of carbon dioxide. The oxygen and carbon dioxide thresholds of some of the cultivated fishes under certain conditions have been determined in India and Indonesia. Studies conducted on the respiratory and digestive waste products of trout in the United States of America have shown that respiration is affected both by low oxygen and high ammonia contents and that high ammonia contents result in distress from lack of oxygen. The conclusion drawn is that trout can be held for indefinite periods at low water temperatures if the water is saturated with oxygen and the metabolic products removed, and that these ammonia products are much more noxious than carbon dioxide. A winter concentration of 0.1 ppm of ammonia has been found to be harmless to trout fry, 0.25 ppm is toxic and 1 ppm indicates serious pollution. There is an increased rate of excretion at high temperatures which saturates the water rather quickly with ammonia products. Similar work on the common cultivated fishes of the Indo-Pacific Region has not yet been undertaken. Experiments conducted in India indicate that larvae and fry of the major carps of India and Pakistan cannot live in oxygen concentrations below 0.5 ppm; in concentrations of 0.5 to 1 ppm they can survive for over 24 hours. Fry 4 to 8 cm in length stand concentrations of oxygen up to 25 ppm for 24 hours or more without any significant mortality. The lethal effect of carbon dioxide varies with the oxygen concentration of the water. While it may be lethal at concentrations as low as 2.5 ppm for larvae and 10 to 15 ppm for fry, when the oxygen concentration is at a low level of 0.5 to 1 ppm, it becomes lethal only at 100 ppm to larvae and 250 ppm to fry at concentrations of 2 ppm or above of oxygen. The haemoglobin affinities of various gases affect the respiration of fishes. But unfortunately our knowledge of the haemoglobin picture of the cultivated fishes in the region is too meager to be useful in standardizing fry transport techniques. The oxygen consumption of a fish is proportional to its weight and increases considerably with rises of temperature. The results of work done so far on Indian carps indicate that the oxygen consumption of larvae and fry can be considerably reduced and maintained at a temperature of about 20°C. As regards pH, it was found that the larvae and fry consume the maximum amount of oxygen when this is between 6.0 and 7.9. Other factors for consideration are the accumulation of ammonia, as mentioned above, the increase in biochemical oxygen demand due to the decay of dead fry or larvae and the increase in the bacterial load of the water. Experimental work has not so far indicated any means of disinfecting the water, as the addition of adequate doses of disinfectants proved lethal to the fry and larvae.

On the analogy of results of investigations on some European fishes, such as the common carp, tench and pike, it has been assumed that the intensity of respiration of a fish is in proportion to

to the second power of the cube root of its weight, as in warm blooded animals. Constants have been worked out in Indonesia in respect of different species from which can be estimated the period in which a given number of fry of a particular size can be transported in a closed container holding 5 liters of oxygen and 20 liters of pond water. The relationship of the intensity of respiration to the weight, on the basis of the above assumption, can be expressed by the formula $C = N \times W \times 2/3T$, where C is a constant, N = the number of fish, W = average weight of a fish in grams and T = time in hours. If the value of the constant is known, the respiratory requirements of the particular species can be estimated with reference to its weight and time of transport. The values established are as follows:

Tilapia mossambica	: 11355.5±325.09
Cyprinus carpio	: 14343.3±771.43
Puntius javanicus	: 9294.4±403.9

Preliminary experiments have given the following range of results for:

Trichogaster pectoralis	: 10000 - 11630
Osteochilus hasselti	: 8837 - 14570
Helostoma temmincki	: 5358 - 7703

Further experiments are necessary to establish the exact values.

The death of fry due to the accumulation of carbon dioxide in the containers has been referred to. It is believed that mortality can be checked if the drop in pH, due to carbon dioxide accumulation, can be counteracted by buffers such as boric acid and secondary sodium phosphate, and experiments conducted in Indonesia have shown that even slight buffering results in an increased survival of fry.

Experimental studies have proved that the metabolic activities of larvae and young fry are much greater than those of advanced fry, fingerlings or adults, the oxygen consumption rate of which is very high on account of greater body weight. Further, the delicate larvae and fry are vulnerable to mechanical injuries. However, in fish culture enterprises the farmer's aim is to obtain the maximum number of fish for rearing in ponds, and so the latest stages at which they can afford to transport may be the fry and fingerlings, except in the case of fishes that breed in ponds, when the transportation of the brood fish themselves may be justified.

The formula expressing the relationship of respiratorial intensity and the weight of fish fry indicates that it will be economical to transport very small fish, as under given conditions a larger number can be transported at a smaller cost. For example, a container of the type used in Indonesia (about 25-liter capacity), which can successfully transport 50 fingerlings each weighing 64 g, can with equal success transport 800 fry weighing 1 g each, over the same period of time.

As mentioned previously, it is generally considered beneficial to condition the fry before transport, to avoid the use of part of the oxygen by the faeces passed into the water and increase in the bacterial load of the water. This might also help in reducing the metabolic rate and the excretion of ammonia products. Some workers are, however, of the opinion that it is not desirable to starve the fry to the point where they may be weakened, because some may die at the beginning of the journey and so foul the water, thus causing mortality among the others.

Transport in Open Containers

Scientific results on the physiological requirements of the cultivated species are of recent origin in the region and much work has yet to be done before a fully satisfactory system of fry transportation can be evolved. However, the available information can be utilized profitably in the improvement of the existing methods and the equipment used. Containers for fry transport in the region are of the open or closed types. The common open containers are the earthen haundies used in India and Pakistan, the unglazed earthenware jars of the Philippines and Indonesia, the different types of bamboo baskets or wooden tubs used in China and Malaya and the flat coal-tarred baskets of Indonesia. Even though earthen vessels are comparatively inexpensive and help in keeping the water cool during transport, there is the great disadvantage that they break easily; also when large numbers of fry are to be transported over long distances, earthenware vessels are very inconvenient to handle. Wooden and bamboo containers are better because of the lesser chances of breakage.

To prevent breakage on the way and to provide arrangements for the easy changing of water, fish transport cans similar to those commor in Germany have been developed and are in use in the Philippines, Indonesia, Ceylon and India. There are two types of such cans made of stout tinned iron plate. The larger measures about 50 cm in diameter at the lower half and is about 38 cm in height.* The mouth is about 20 cm in diameter and has a pressed-in perforated lid to admit air and at the same time prevent the water splashing or the fish from jumping out. The can is fixed on a wooden base to lessen heating through contact with warm surfaces during transport. A close-fitting cloth jacket, which is kept moist, helps to maintain a uniform cool temperature during transport, even when the container is exposed to the sun.

The cans used in the Philippines have a separate drain pipe attached to the side on the upper half near the mouth; but in India, draining and replenishing is done through the perforated lid. Cans are about three-quarters filled with clear, cool, natural, decanted or filtered water. During the journey the disturbance caused by jolting keeps the water aerated. Where halts are made the can is examined and all dead fish removed. Over long distances the addition of fresh water may be necessary every hundred miles or every four hours. Chlorinated drinking water is not suitable for the purpose, but water from railway hose pipes, taps and the like can be used after allowing it to cool and settle for about an hour and a half. The can is first partially drained by tilting it with the lid on and allowing the water to run out; the fresh water is immediately poured in from a moderate height through the perforated lid. If the water to be added is considerably warmer or of markedly different properties it should be added in small quantities so that the change is not sudden. In the absence of good water, aeration is effected with a garden syringe or by agitation with a hand dipper. The Department of Fisheries in the State of Orissa (India) fits ordinary semi-rotary pumps (1.27 to 2.54 cm sizes) to the containers for the aeration of the water. The delivery pipe has two rows each being at such an angle to the other that in action two batteries of water jets are produced, one on the near side and the other on the far side, spraying the entire surface. Fry will travel in such containers to distances of over 480 kilometers with a mortality of only about 5%.

Other types of transport containers exist but are not in common use.

On train journeys it is best to put the cans in the van nearest to the engine, so as to avoid violent jolting which may affect the fish. Fifty to a hundred fingerlings are generally carried in the larger type of can in Madras State, whereas no more than ten are carried in the smaller. The Indonesian tin plate cans are roughly similar to those used in India.

* Smaller and shallower cans are also available.

A can has been developed specifically adapted to tropical conditions, in that the lid is designed to hold about 1 kg of ice. The bottom is oval and so balanced that two of them can be carried by hand or on a bamboo pole.

The flat, shallow, basket-like containers of tightly plaited bamboo are very useful. Treated with coal-tar they are completely water-tight, almost unbreakable, light, inexpensive and easy to store. Equipped with a lid of coarse wickerwork they can be immersed during transport in a canal or pond with a full load of fish. A 60 cm diameter basket can hold 180 carp weighing 60 g each; one of 80 cm diameter, 250 fishes of the same weight, and one of 100 cm will carry as many as 500 if the water is changed from time to time. Special 15-liter baskets can accommodate 10,000 fry 3 cm long or 2,000 of 5 cm. Adult carps need about 1 liter of water for every 250 g of fish during transport. Oval wooden 150-liter casks are used in Indonesia to ship brood fish all over the archipelago. They hold up to 36 kg of live fish.

The Chinese fishermen consider that fry smaller than 40 mm in length are unsuited for long-distance transport. Baskets and tubs of various sizes are used, the largest measuring as much as 2 m in height and 1.9 m in bottom diameter which carry about 50,000 fry. The water in the container is kept agitated throughout the day and night with wooden paddles. If the agitation stops, even for a few minutes, serious mortality can result. The foul water is continuously baled out in small quantities and renewed. For every three to four containers four to six experienced attendants are necessary and, if the weather is favorable and the attendants work regularly, the survival rate is about 60% on journeys taking less than six or seven days. On long journeys over-night halts are made wherever possible at selected spots. The fry are then liberated into a net trough fixed in a pond on bamboo poles and fed with yolk of egg and flour spread on a small rectangular piece of wood. On very long journeys the fry are fed with cooked yolk of eggs or soya bean ground into a fine paste. Great care is taken to see that the food is all consumed and that nothing is left behind to foul the water.

Two types of boats with live holds having holes to allow water to enter are used for river transport. One type, about 8 meters long, has four compartments with several holes which can be closed when desired. The walls of the hold are lined with fine ramie cloth to prevent the escape of fry. In such a boat 1,000,000 to 1,500,000 fry can be transported at a time. In the second type, with a capacity of 10,000,000 fry, there may be six or seven compartments with arrangements for inter-communications through screened openings in the walls. Each hold has three holes at the bottom, each fitted with a piece of short perforated bamboo pipe. The outer end of the pipe projects into the river to produce sufficient pressure to drive water through the perforations, the force of flow being adjusted by manipulating the level of the pipe. The middle compartment of the boat receives the water from the other compartments and a water wheel pumps it out; thus a constant circulation is maintained.

Special types of live fish boats, known as pamandawan or hatiran in the Philippines, are used to transport milkfish fingerlings over long distances. Made of wood, dug-out or flat-bottomed, they have two or more well-screened holes to allow the free entrance of water. Similar boats are used in Indonesia. The holes are often provided with short bamboo tubes, screened at the inner ends. The outer ends are cut in such a manner that the rate of flow of water into the boat can be controlled; adjusted to face the direction in which the boat is moving, more water enters the boat, while if it is turned backwards the inflow is reduced. Dug-outs measure from 10 to 20 meters in length and are propelled by outboard motors. Larger flat-bottomed barge-like boats can transport 15,000 to 50,000 fingerlings, depending on the size. Trains of these boats are often towed by tugs.

The boats are thoroughly cleaned, the inlet arrangements checked and partly filled with water before the fingerlings are introduced. The holes are then opened to admit water and simultaneously one or two men start baling water out from a special enclosure of close-meshed bamboo screen, thus maintaining a continuous flow of well-aerated water. Transport during inclement weather and through very shallow or turbid waters is avoided as far as possible.

Special fry transport trucks provided with pumping and cooling arrangements to maintain a circulation of cooled oxygenated water are very efficient in western countries, but in the Indo-Pacific Region there appears to be very little prospect, at present, of using them on a large scale, due to the unsatisfactory condition of roads near fry-collection and nursery centers and the economic status of the fish culture operatives.

Transport in Closed Containers

Some of the defects of transport in open containers can be obviated by carrying fry in hermetically sealed containers with an excess of oxygen. Cans of the type used for kerosene and petrol, and galvanised iron drums have been used for the purpose. These containers must have a sufficiently wide opening with an airtight lid and fitted with two metal pipes, preferably reaching the bottom, one with a narrow bore for oxygen. If the pipes reach the bottom the possibility of the sharp ends injuring fry will be minimised. However, very often the water displacement pipe reaches to only one-third of the container's depth, facilitating the addition of the required amount of oxygen. For very small fry or larvae the lower ends of the tubes should be covered with fine meshed netting to prevent their escape.

To use, the container receives more than two-thirds of clean, filtered pond water, the fry are put in through the wide mouth, and then the container is filled with water to exclude all air. The lid is tightly closed and oxygen is then introduced through a regulator and the narrow pipe from an oxygen cylinder. Since the can is full of water, a volume of water equal to the volume of oxygen introduced will be displaced through the second pipe. When sufficient oxygen has entered, both the pipes are hermetically sealed.

Although the number or weight of different species of fry or larvae that can be carried in a closed vessel under a given set of conditions has not yet been determined accurately, some available data enable such estimates to be made. At the Inland Fisheries Research Station, Barrackpore, India, 18-liter cans are used to transport fry of the major carps of India in the presence of about 6 liters of free oxygen. Such cans will hold 900 to 1,000 fry 1 to 2 cm long (about 285 g) and can be safely transported by plane for over 20 hours. The fry should be conditioned for about six hours in water that has been left to settle for some time. Transport of fry above 5 cm in length is uneconomical. The experience gained at the Hong Kong Fisheries Research Station indicates that the following data can be used as a guide for the transport of Chinese carps (grass carp, big head, silver carp and common carp):

Number of Chinese carp fry that can be transported in a container of 18.5 liter capacity containing 8.5 liters of free oxygen

Size of fry in mm	Wt. per 1000 fry in g	No. of fry	Amount of free oxygen per g of fry in ml
10-20	50-200	4000-5000	42.5
30	450	1500-2000	12.9
40	800	800-1200	10.6
50	1500	500- 800	5.7
60	2500	400- 500	3.4
70	3000	350- 400	2.8
80	3500	250- 300	2.4
90	4500	200	1.9
100	6000	150	1.4
110	8000	100	0.85
120	12000	80	0.70

From the studies on the physiological requirements of fish larvae and fry, conducted in India, it is inferred that the closed container will be suitable for fish fry transport only if the duration of the journey does not exceed 20 to 24 hours, otherwise the accumulating carbon dioxide and other metabolic products may prove lethal to the fry and cause serious mortality. However, the Indonesian experiments show that the addition of suitable buffers may be effective in counteracting this.

FRESHWATER POND FISH CULTURE

Indigenous Ponds

Freshwater ponds are a distinct feature in many villages in the Indo-Pacific Region. A large number of them are not drainable, but even so they have a potential value for fish culture. The need is to make use of these ponds, rather than to construct new ones.

A classification of ponds can only be very loose since they exist in many forms and originate in various ways.

Village ponds are water reservoirs used for such purposes as bathing, washing and watering stock. They are often communally owned. Homestead ponds are found in low-lying areas, such as deltaic regions and coastal tracts where they were dug to obtain earth for house construction and reclamation of low-lying land. In regions with intensive agriculture, ponds of various sizes are dug in fields and gardens for watering crops and cattle. Irrigation ponds are larger in size to collect water from catchment areas for storage. Spill ponds (the bheels or bhils of India and Pakistan) are constructed in spill areas of rivers formed by the changing course of rivers. Moats around forts, villages and small towns are not common, but do occur in China, India and Ceylon. Open mine pits and quarries are numerous in some places, but are seldom suitable for cultural purpose.

Proper care is seldom bestowed on the upkeep of ponds. They may be overgrown with vegetation and form breeding places for mosquitoes. Dense growths of hardy aquatic plants on the pond surfaces usually prevent the penetration of light to deeper water layers, and they kill submerged vegetation. Plants die off and rot, and deposits of debris are formed at the bottom. Such ponds are often perennial and rather deep, with a dense population of predatory and weed fishes. For want of proper embankments, drainage from surrounding areas may flow into them. Smaller ponds may dry up during certain periods of the year. Homestead, farm and garden ponds are generally less than one hectare in size and are better maintained than the larger village ponds.

Irrigation ponds are called bunds in India and waduks in Indonesia. They have strong embankments on one, two or three sides. Some are perennial and other dry out seasonally. Spill ponds are sometimes as large as 250 ha, two or more meters deep and many have dense growths of water weeds.

Improvement of Indigenous Ponds

The three main types of ponds needed for a self-supporting fish-culture enterprise are nursery, rearing and stocking ponds. Small seasonal ponds can be used as nurseries and for rearing, and large seasonal and perennial ponds for stocking, but most of them have to be improved before they are suitable for cultural purposes.

If rank vegetation exists, it is essential to eradicate the growth in such a way that there will be little chance of quick reinfestation.

It is most desirable to drain and desilt the ponds before they are used for fish culture. Draining is not difficult when the ponds are situated immediately above low-lying areas. When they are not, the expenses involved will be high, but the removal of excessive organic debris from the bottom of old, perennial ponds will often be worth the labor involved. Mechanical water-lifters and motor-driven pumps are now fairly common in the region. The excavated silt

can be used for repairing embankments or as a fertilizer for agricultural crops. Even when it is not possible to drain the pond, due to restricted water supply for refilling or because it is very deep, it may be possible to remove some of the excessive organic deposits from the bottom with machines. This is done in China with flat bamboo shovels fitted with long handles to reach the bottom of the pond. The mud is collected in boats or thrown on the banks. The banks should be raised and strengthened wherever necessary.

Wherever possible each pond should be provided with an inlet and an outlet, preferably fitted with pipes of concrete, galvanised iron or wood, and protected with fine-meshed sieves to prevent the entry of extraneous animals and the escape of fish.

Large spill ponds should be divided into smaller units by the erection of suitable cross dikes the better to control pond conditions.

Specially Constructed Ponds

For really efficient fish culture ponds specially constructed for the purpose are most desirable. Pond construction is essentially an engineering matter and most fish culturists have little training in this field. This often leads to selection of unsuitable sites and faulty construction resulting in considerable loss of money and effort. Constructional details have to be worked out with due reference to the topography of the area, nature of soil, water supply, etc., and it is therefore always advisable to seek the help of technicians familiar with this kind of work. Pond construction is mostly done in the Indo-Pacific Region by human labor, and mechanical devices such as bulldozers, carry-all scoops and rippers are not yet common, mainly because the farmer cannot afford the heavy expenditure involved.

Selection of Site

In general terms it can be said that the most suitable sites for pond construction are those with fertile soil and an adequate water supply throughout the year. Low-lying deltaic areas and coastal districts are generally well suited and so are hilly areas with good irrigation facilities. In coastal regions ponds depend mainly on rain water; in hilly areas an additional supply of water should be available from canals or rivers. Easy access is an important factor in selecting sites for ponds. In the absence of roads it will be expensive and difficult to bring equipment and stocking material to the pond farm and to send the produce to the markets. In deltaic districts and those adjoining rivers, canals and lakes, water transport should be feasible and inexpensive.

If rainfall runoff has to be used as the only source of water supply, a ratio of 10 hectares of catchment area to one hectare of pond is required if pasture land is involved, a slightly higher ratio for wood-land, and smaller for land under cultivation. The most suitable soil for pond construction is clay. Loamy soil, marl and peat are also satisfactory. If the soil is slightly porous it can be improved by puddling with clay. Sandy soils, or limestone outcrops are not suitable because their waterholding properties are very low. Unless the site has a high water table it will be very difficult to keep a sufficient depth of water in the pond. If the soil is rocky, excavation will be expensive and the excavated soil may not be suitable for the embankments.

Saline deposits will render a pond unsuited for purely freshwater fishes. If such fishes are to be cultured, the soil must first be improved by flooding with fresh water to wash out the salt. On the other hand, brackishwater fish can be reared.

General Layout

A fish farm should preferably be self-sufficient, so that all operations from breeding to final cropping can be conveniently done. Breeding and segregation, nursery, rearing and stocking ponds, and wintering ponds in cold climates, are the main divisions necessary. An essential requirement is that the various ponds can be supplied with water and drained independently. The ponds should be arranged in series, with the water inlet at one end and the drainage at the other. The size of various types of ponds has necessarily to be determined with reference to the type of fish cultivated. The following proportions of pond are recommended for the cultivation of the common carp in association with Tilapia.

	Area in m^2	Approx. percentage
2 segregation ponds	500	0.4
2 or 4 carp spawning ponds	400	0.3
4 nursery ponds	5,000	4.0
4 rearing ponds	10,000	8.0
10 or 20 stocking ponds	100,000	80.0
2 Tilapia spawning ponds	5,000	4.0
Dikes	4,100	3.3
	125,000 m^2	100.0

Similarly, for the cultivation of gourami the following proportions have been suggested:

	Area in m^2	Percentage
One head pond (a reservoir where water from a supply channel can settle and produce plankton).	100	1.0
Two or more breeding ponds.	1,000	10.0
Three rearing and stocking ponds, house site and dikes	8,900	89.0
	10,000 m^2	100.0

Stocking ponds can be of any size, but they are generally not larger than 5 ha as there may be difficulty in harvesting the crop if they are larger.

The whole fish farm should be provided with good fencing to prevent the entry of unwanted intruders. Shade trees protect the fish from the intense heat of the sun and also add to the beauty of the place. Marginal or central ditches are often dug in shallow ponds as retreats for the fish on hot days. These ditches are also useful for draining the ponds.

Building the Pond

In the Indo-Pacific Region, expenses of pond construction can generally be kept low by using cheap manual labor; expensive power machinery is not as a rule justified so will not be discussed.

Ponds can be of almost any shape. A rectangular pond about 50 m wide is probably the most convenient shape for netting operations. The depth and the height of the embankments will depend on the climatic conditions and the use to which the pond is to be put. In most of the countries of the region the winter is not so cold as to freeze the water, so the ponds can be comparatively shallow. Depths of 0.5 to 1.0 m for nursery ponds, 0.6 to 2 m for rearing, and 1 to 2.5 m for stocking ponds are generally considered adequate. But in a few areas, with cold winters, stocking ponds have a depth of 3 to 8 m. Where there is excessive evaporation or temperature variations, deep ponds are recommended. Since costs of construction increase in proportion to the depth, excavation should be restricted to the minimum. When a fish farm is built as a self-sufficient unit, with nursery and stocking ponds, it will be advantageous to have it so arranged that water from a stream can be let into the various sections by a system of channels, pipes and sluices.

The site should first be cleared of all trees, brush and similar growth. The surface organic deposits should be kept aside and later put into the pond as fertilizer. The surface should also be kept for use later in facing the embankments, on which grass and other vegetation should be planted. The shape of the embankment must depend on the type of soil, but generally a slope of 1 in 3 is adequate. Sandy or other porous soils should have a less steep slope, say of 1 in 5. For small ponds up to 1.5 m deep, a slope of 1 in 2 will be satisfactory if the embankment is made of heavy material. When the banks are higher than 3 m and are to be used as roadways, the width should be about 2.5 m. The crest of the embankment should be about 0.5 to 1 m above the mean level of the pond water, and in areas with flash run-off, additional free board may be necessary. With these requirements in mind, it will be possible to determine the width of the embankment base. If this is not done in advance, the provision of the correct slope may be difficult.

The embankment foundation should go down to firm, impervious soil. If the foundation soil is porous, a trench 30 cm wide should be dug along the center line of the dam wall down to the impervious layer and filled with damp clay, each layer being rammed as tightly as possible. This procedure may be advantageous even with other soils, as the junction between the fill and the surface ground is often a weak point and may give rise to seepage. If there is a rock outcrop it will be necessary to build a concrete wall in the rock and extend it up into the fill. The advice of an engineer should be sought when such circumstances arise. The fill from the embankments is generally obtained by the spoil from the pond. It should be placed in layers over the full length and width as the wall rises, and not in sections, as otherwise leaks may develop due to the variations in the material and differences in compactness. Allowance should be made for settling, which may be, on average, one meter for every five meters of height, when completed. The corners of the pond should be protected against erosion. The top and slopes should be faced with soil in which planted grass will grow. This will bind the soil and prevent erosion. Small nursery pond banks in China and Indonesia are reinforced with planking or bamboo gratings held in place by wooden piles driven deep into the earth at regular intervals.

Water Control

All water supplies to a pond should pass through an inlet pipe or sluice, and provision for this should be made when the embankment foundation is being built. The inlet is usually located at the highest portion of the pond site, adjacent to the source of water supply. From this point the pond bed should gradually slope to the deepest portion where the drain is located. It is a general practice to provide fine-meshed screens for the inlets, to prevent the entry of undesirable animals. The materials for the pipe or sluice will depend on the quantity of water it has to carry. Concrete and steel pipes and sluices are usual in western countries, but bamboo pipes, hollow palm stems and wooden sluice structures are more common in the Indo-Pacific Region.

A simple way of making a wooden sluice is to nail together four planks, 30 cm to 60 cm wide and long enough to pass through the embankment base, rectangular in section, open at both ends. A sliding wooden gate at one end will control the flow. For ponds over 1 ha in extent a concrete sluice may be necessary, the dimensions of which will vary with the size of the embankment and that of the pond. Arrangements for complete drainage are necessary. The drain pipe or sluice can have arrangements for controlling the water level. A 10 to 15 cm pipe is sufficient for average sized ponds, and should be built into a concrete or a similar wall inside the embankment to hold it in position.

In hilly areas ample spillways are often necessary to prevent damage by floods. Very few fish are likely to be lost during floods over a wide spillway in which water flows in a shallow stream. Shallow spillways may also avoid the necessity for screens which have the disadvantage that they are likely to get clogged. A 15 cm wide spillway, properly protected to prevent erosion, is recommended for every 0.4 ha of catchment area.

When the pond is used for watering stock, the animals should not be allowed direct access, but the water should be pumped or bailed.

Prevention of Seepage

It is a common experience in many localities that ponds, when filled, do not hold water satisfactorily until sufficient silt has precipitated at the bottom. This is especially so on gravelly or sandy soil. The bottom of such ponds should be levelled and well consolidated by rolling or ramming and a layer of mud clay then spread to a thickness of over 20 cm on the bed. The inside of the embankments should also be lined with clay. Water should be admitted into the pond and allowed to remain for a long time. The trampling of livestock or laborers in the pond while filling, will help. A layer of loam should be spread over the clay to encourage the growth of fish food.

Some Chinese fish culturists in Singapore prevent seepage in sandy soil by covering the bottom with cement and planking the sides. Since no natural food is produced in such ponds, artificial food has to be supplied in adequate quantities.

PHYSICO-CHEMICAL PROPERTIES OF WATER AND SOIL

Water is the basic element in fish culture and its specific properties as a cultural medium are naturally of great significance in the productivity of a pond. Pure water is unable to support living organisms but its content of nitrogen, phosphorus, potassium and calcium salts, dissolved organic matter and gases like oxygen, nitrogen and carbon dioxide determine to a large extent the productivity. The physical features, such as the depth of water, shore conditions, water movement, light penetration and temperature, also influence the biota and the growth of fish. Similarly, the physico-chemical properties of the pond soil are of greater significance than is generally realised. When the soil conditions are not favorable, the production will be limited. Very few scientific investigations on the physico-chemical properties of soil and water of fish ponds have been conducted in the region and accurate information on the optimum properties for the culture of different species of fish have yet to be obtained. A classification of the types of water, based on their capacity to produce fish food, and the level of natural or artificial replenishments in terms of nutrients needed to maintain them in a state of optimum productivity, will be of immense help in standardising fish culture techniques and expanding the industry on a scientific basis. In the absence of the necessary scientific knowledge even the advice of

hydrobiologists must be based on empirical experience. The fish farmer often recognises the suitability of water by its color and taste. In India the crystal clear water from hill streams, artesian wells and the like is considered barren, and the slightly brackish water from canals near the coast, samples of which at first are slightly turbid and change a little later to a brownish color, are also unproductive. Conditions are sometimes improved by applying suitable quantities of manure and by the addition of lime to keep the water slightly alkaline. These measures promote the growth of a bloom of phyto- and zooplankton; when the water becomes green, the pond is suitable for the culture of fish.

Physical Properties of Pond Water

The depth of water in a fish pond is most important since the penetration of light to the bottom contributes in a large measure to the pond's productivity. The layers of water below 3 to 4 meters in temperate regions and below 1.5 to 2 meters in tropical regions have little significance in biological productivity. Shallow waters get warm rapidly and provide optimum conditions for life and reproduction. The assimilative functions of submerged water plants mainly take place at a depth of 0.01 to 1 m. However, fish ponds should not be too shallow, as extremely high temperatures may adversely affect productivity and may lead to a loss of fish. In Indonesian carp ponds a minimum depth of 0.3 meters is considered suitable for healthy pond life.

The sun's heat in tropical countries keeps the surface temperature constantly high, thereby creating a stratification in the pond. Three distinct water layers are recognised, namely (1) the epilimnion or the warmer waters of the surface zone, (2) the thermocline, a thin middle layer, where the temperature drops abruptly, and (3) the hypolimnion or the cooler water at the bottom. This thermal stratification may not be prominent in shallow ponds. It was generally believed that the surface layer of water in tropical climates does not mix completely with the layer below three meters except in ponds exposed to strong wind action. However, observations conducted in Indonesia have shown that instead of an annual turn-over, as found in temperate climates, a daily turn-over takes place in tropical ponds. During the nights, circulation takes place, bringing about a mixing of the water. This turn-over is of extreme importance in the circulation of oxygen and nutrients in pond water.

Within limits, all life processes in a water area are enhanced by an increase in temperature. A rise in temperature induces the migration of surface biota to deeper waters. High temperatures indirectly influence the dissolved oxygen content of the water, the oxygen consumption of the biota and the mineralization of organic substances. The oxygen content of the water decreases proportionally with a rise in temperature but super-saturation helps to bridge-over periods of extremely high temperatures. Even though, generally speaking, warm water is better for fish production, it is emphasised that different species of fish have different levels of temperature tolerance. Unfortunately, information on these aspects of most of the cultivated fishes of the region is very limited. In practice, when the water temperature is suspected to be reaching the lethal limit, fish culturists provide suitable shade or shelters in ponds to protect the fish. Deep trenches are often dug on the pond-bed, where the fish can remain during the hot hours of the day, but because such trenches often become the haunt of predatory fishes, some fish culturists prefer shade, in the form of thatched platforms, over a part of the pond surface.

The turbidity of the water in a fish pond may be due to suspended clay, silt and finely divided organic matter. It may be only temporary, due to rains, floods, drainage inflow and mechanical disturbances, or permanent on account of the nature of the soil and constant wind and wave action. Turbidity is an important limiting factor in the productivity of a pond. Light can penetrate deeper into clear water and influence the migration of food organisms and also induce the growth of plants in deeper waters.

The photosynthetic activity of plants in turbid water will be reduced and the fish fauna needing clear oxygen-rich water will be replaced by a predominently labyrinthiform fauna. The turbidity tolerance of various species of cultivated fishes is not yet known, but a few of them have been found to be extremely tolerant of turbidity fluctuations. The carp, Puntius schwanefeldi, which is a clear water fish, has been observed to be tolerant of a turbidity ranging from that of clear hill streams to as low as 4 cm, in terms of Secchi's disc, sharing this property with other Puntius species. The cat fish, Pangasius pangasius, is able to live in water with a visibility as low as 2 to 5 cm in terms of Secchi's disc. Profuse growth of plankton, which may reduce the visibility of water, is a sign of fertility, but turbidity due to silt or mud may be harmful to both fish and their food organisms. The production of fish food will decrease with the reduction of sunlight, and sand and mud may smother the food organisms. It is therefore essential to prevent the water from becoming too turbid with silt or mud.

Water movement or a current of water is necessary for the survival of certain fishes and especially for their breeding. Most of the cultivated fishes of the region can thrive in stagnant water, but species like Rohu, Catla, Mrigal and Nilem require flowing water to spawn, even though they grow and fatten well in lentic environments.

Chemical Properties of Pond Water

Dissolved Oxygen. Of the various chemical factors governing fish life in a pond, the dissolved oxygen is of primary importance, as all fishes, as well as their food organisms, depend on dissolved oxygen for their respiration. The aerobic bacteria are also major consumers of dissolved oxygen. Besides the atmospheric oxygen that dissolves in the water, plants release oxygen during the process of photosynthesis. The rapid water circulation in tropical ponds helps the process of aeration considerably. Accurate estimates of the aeration constants of different tropical waters remain to be made. The oxygen-carrying capacity of water varies inversely with its temperature, and an increase in temperature results in the decrease of oxygen. The following figures show the normals.

Temp. (^{o}C)	Oxygen (in mg per liter) p.p.m.
0	14.57
5	12.74
10	11.25
15	10.07
20	9.10
25	8.27
30	7.52

While the dissolved oxygen content decreases with increases in temperature, the oxygen consumption of fish increases with a rise in water temperature. It has been found that in cold-blooded animals the rate of oxygen consumption and consequently the release of carbon dioxide generally doubles with a temperature increase of 10^{o}C. This would lead to a consideration of the factors that might contribute to the diminution or depletion of oxygen in fish ponds. For instance, the absence of aquatic plants which contribute to the oxygenation of pond water may be a cause of oxygen diminution. Putrefaction of organic matter uses up considerable quantities of dissolved oxygen and may also lead to oxygen depletion. This often happens in tropical countries during rainy periods, when the sky is overcast for long periods. A sudden rise of temperature during the summer may have a similar effect, as a good quantity of the dissolved oxygen may be driven out of the water.

Very little information exists on the oxygen-consumption rates of different age groups of cultivated fish. An oxygen content of less than 3.5 mg per liter is lethal to common carp in Europe. Similarly, oxygen contents below 5 mg per liter are known to be critical for salmonid fishes in summer. Ordinarily, a concentration of 5 ppm at a temperature of over 20°C, which is equivalent to a saturation of 60% to 70% in a temperature range of 20°C to 30°C, is considered sufficient to maintain freshwater fish in a healthy condition. Supersaturation of oxygen very seldom has any ill effect on fish, even though in certain rare instances it has been found to cause mortality by the formation of gas emboli, which may block the capillaries in the gill filaments.

Biochemical Oxygen Demand

The biochemical oxygen demand (B.O.D.) is the oxygen used up by unstable organic matter for its stabilisation in a water area and is therefore dependent on the quantity of organic substances in it. It is an important indication of the amount of organic matter in a pond. The stabilisation of organic matter is brought about by aerobic bacteria. Since complete stabilisation requires a long period, for the sake of convenience the determination is generally made after five days incubation of the sample at 20°C. A sample of water with no significant organic pollution has a B.O.D. of the order of 2 ppm, 5 days, 20°C. When there are large organic deposits at the pond bottom, or when the water gets polluted by the introduction of effluents, the B.O.D. may rise, resulting in the depletion of oxygen and consequent mortality of pond fish.

Hydrogen-Ion-Concentration. The hydrogen-ion-concentration (pH) is an often used index of the water conditions in a pond. While a pH of 7 indicates a neutral reaction, pH above 7 shows an alkaline reaction, and a pH below 7, an acid reaction. The pH of the water is indicative of its fertility or potential productivity. A slightly alkaline reaction is of great help in the conversion of organic matter into assimilable substances, such as ammonia and nitrates. A pH of 7 to 8, i.e., a feebly alkaline reaction, is a characteristic of good water, suitable for fish life. The presence of dissolved calcium bicarbonate is mainly responsible for the maintenance of such an optimum range of pH. Adequate quantities of calcium bicarbonate will have a buffering action and prevent pronounced variations of pH. Water acidity, besides directly affecting fish, may affect the pond life as a whole by impeding the circulation of nutrients by reducing the rate of decomposition, and inhibit the nitrogen fixation. A satisfactory pond water, having adequate acid-combining capacity, will not have a pH range wider than 6.5 to 8.5.

Many fishes are able to tolerate wide pH variations. The brook trout has a pH range of 4.6 to 9.5, and swamp fishes such as Trichogaster pectoralis, T. trichopterus and Ophicephalus punctatus are known to live well in water ranging in pH from 4 to 9. But there are many others that are rather sensitive to low pH values. Common carp, big head, grass carp, silver carp, black carp and gourami have died when heavy rain water decreased the pH from about 7.2 to 4.6. Trout fry exposed to acid water are adversely affected.

Generally speaking, a pH lower than 5.0 is unsuitable for fish life. It has been observed that a low pH may adversely affect the reproductive activity of fish such as trout. Waters of pH 4.5 to 6.5 can be improved by the application of sufficient quantities of lime to raise the pH to about 8, but below 4.0 little can be done.

Alkaline Reserve. The importance of alkaline reserve, also known as the acid combining capacity and titration alkalinity, in judging the suitability of pond water for fish life has not been fully realised by fish culturists. Even though small amounts of carbonates of magnesium, sodium and potassium may slightly influence the alkaline reserve, for all practical purposes, it can be expressed as the calcium content of the water. The process involved is somewhat as follows:

Suppose, at an alkaline reserve of 2 cc of normal hydrochloric acid per liter, which corresponds to 56 mg of calcium oxide per liter, the water contains 88 mg per liter of calcium bicarbonate and 2.3 mg per liter of free carbon dioxide; if, due to the photosynthetic activity of the aquatic plants, it loses 1 mg of free carbon dioxide, the pH will rise. A part of the calcium bicarbonate dissolved in the water will split up into calcium and free carbon dioxide until a fresh equilibrium and a corresponding pH is brought about. The calcium carbonate is deposited on the plants or in the water and settles at the pond bottom; the alkaline reserve drops. The lime applied to a pond absorbs the carbon dioxide and brings about the same set of conditions. In the reverse manner, when water contains free carbon dioxide higher than 2.3 mg per liter and the pH is consequently low, the excess of carbon dioxide connects the calcium carbonate deposited on the pond bottom into calcium bicarbonate; the alkalinity reserve increases, raising the pH and establishing the necessary equilibrium. This process takes place in a pond almost continuously and accounts for the fluctuations in pH. Based on the alkalinity reserve, waters have been classified by Hey (1941) and Huet (1947) as follows:

(1)	0 - 0.15 cc normal HCl per liter	- too acid for fish culture	
(2)	0.15 - 2.0	- do -	usable
(3)	3.5 - 6.9	- do -	optimum
(4)	7.0	- do -	and above - too hard with a tendency to deposit alkaline salts

Free Carbon Dioxide. Water contains free carbon dioxide mostly from the decomposition of organic matter, in varying quantities from the atmosphere, or as a result of the respiration of aquatic animals and plants. Plants assimilate carbon dioxide for photosynthesis and release oxygen during the day. Accumulation of free carbon dioxide generally takes place at night.

A high carbon dioxide content of water is lethal to fish life and, besides preventing the oxygenation of water, it might also adversely affect the extraction of dissolved oxygen from the water. Although some information on the lethal carbon dioxide thresholds of the spawn and fry of a few cultivated fishes have been determined, very little work has been done with adult fishes. Based on general observations it may be said that 5 cc per liter is the lethal limit for healthy fish life. A high concentration of carbon dioxide has been observed to increase losses of fry and the number of deformed specimens in trout.

Nitrogen. Nitrogen forms one of the basic elements of fertility in ponds. Certain quantities of nitrogen may be taken into soil or water from the atmosphere by rain or lightning. There are also soil bacteria that can fix atmospheric nitrogen and thus make it available to the phytobiota. In addition, certain types of blue-green algae, living on the muddy bottom of ponds, probably are capable of aerobic nitrogen fixation. However, ponds derive the major supply of nitrogen from the putrefaction cycle. Anaerobic, aerobic and facultative bacteria bring about the decomposition of vegetable and animal matter. The nitrogenous compounds in waste matter are first broken down by the anaerobic bacteria into ammonia, and their sulphur compounds are converted into hydrogen sulphide and certain other compounds. If the supply of oxygen is slow, this phase will be prolonged, resulting in the formation of gaseous substances. However, when free oxygen becomes available, the aerobic bacteria take up the work of oxidation and the ammonia is converted into nitrites and nitrates. Nitrates are the end products of this cycle and form the main source of nitrogen for various forms of life. The nitrates can be broken down by the action of certain micro-organisms into nitrites, then into oxides of nitrogen and finally into free nitrogen, a process known as denitrification.

This putrefaction cycle is of extreme importance in the maintenance of a balanced pond life. Adequate quantities of nitrogen compounds, especially nitrates, are essential for the productivity of the pond. The quantities obtained by the natural processes may not always be sufficient for a high production of fish. The best production of plankton is obtained when the water contains 4 ppm of nitrogen with 1 ppm of phosphorus and 1 ppm of potassium. The relation between nitrogen and carbon concentrations is also of great significance. Nitrogen fixation by bacteria takes place on a pond bed rich in carbohydrate materials which are essential both as a source of energy to anaerobic forms and a constituent of bacterial protoplasm.

The ammoniacal nitrogen content of water is an index of the degree of its pollution. Its concentration in unpolluted water is never more than 0.5 ppm. Healthy growth of fishes can be expected in waters containing less than 2 ppm of dissolved ammonia. The toxic effect of ammonia compounds is at a maximum in pH ranges of 7.4 to 8.5. Concentrations of ammoniacal nitrogen up to 4 ppm at pH 7.3 to 7.5 have no ill-effects on tilapia, common carp, big head, grass carp, silver carp and black carp.

Hydrogen sulphide. Hydrogen sulphide can be a severe limiting factor in fish ponds. It is formed by anaerobic bacteria, and sometimes accumulates in ponds having a thick layer of organic deposits at the bottom. In muck soil the gas may be formed by fire. Due to the high organic content, dry muck may burn and, combustion often being incomplete, sulphides are formed instead of sulphates. When the alkaline sulphides are carried into slightly acid wet muck, hydrogen sulphide is formed and is carried off in solution. This may ultimately be carried into ponds and an accumulation of it may cause severe fish mortality. A concentration of 6 ppm of hydrogen sulphide will kill common carp in a few hours. Aeration of the pond by mechanical agitation helps to a large extent to free the pond of hydrogen sulphide.

Phosphorus. Unlike nitrogen and carbon dioxide, phosphorus is not derived in a pond from the atmosphere. Even though present only in very small quantities in natural waters, phosphates, together with silica, are intimately associated with the life cycle of phytoplankton. The nitrogen supplied by the nitrogen-fixing bacteria and phosphorus released from dead organisms give rise to the growth of phyto- and zoo-biota in the water. A concentration of 1 ppm of phosphorus is the optimum for good growth of plankton.

Potassium. Potassium is another important chemical constituent that determines the fertility of a pond. The nature of the pond bed is an indicator of its potassium reserve. Sandy soil is often poor in potassium and a clayey soil generally rich in it. It is readily absorbed by plants and is specially effective in stimulating the growth of aquatic flora. Potassium stored in the plant tissue is released back into the water directly, or from the pond bottom as a result of the decomposition of the plant bodies that die and settle there. A concentration of 1 ppm of potassium in combination with 1 ppm of phosphorus and 4 ppm of nitrogen is believed to be most favorable for plankton production. It has been observed that potassium is able to improve the growth of young common carp more quickly than of older fish. It is thought that the effect of potassium may possibly be indirect and that it facilitates the phosphate cycle by releasing dilute acid.

The Role of Pond Soil

The role of the chemical constitution of the soil in the productive potential of a pond is generally not fully understood. There are often significant differences in the productive capacity of ponds situated in similar surroundings. The productivity of an unfertilized pond may sometimes be the same or more than that of fertilized ones, which can often be traced to the chemical and physical properties of the soil. The soil fertility is of special importance in the growth of benthic vegetation. While water fertility will contribute largely to the production of plankton, soil fertility will under favorable physical conditions induce a good growth of benthic flora.

This is the reason for the special care taken by the milkfish culturists of South East Asia in selecting sites with alluvial soil for their brackishwater ponds. The quality of the soil underlying the pond bed and the organic deposits over it should be given full consideration in an appraisal of its productive capacity. The pond bed releases nutrient material into the water and helps in the fixation or chemical combination of such substances released in the pond itself or introduced from outside. Benthic biota grow and derive nutriment and shelter from the pond bed.

Production in ponds with a bottom rich in fertilizing elements is much greater than in those with poor soil. When the soil contains excessive quantities of alumina and ferric compounds, the water may be rendered acid by the slight colloidal solution produced. In tropical countries, the soil may often be poor in calcium and rich in iron oxide and alumina. This accounts for the soils of such low pH as 4.7 to 5.5 in countries like Malaya. Certain coastal soils become more acid due to the oxidation of sulphur compounds in decaying plant material. Peaty areas, particularly swamps, may have a pH as low as 3.6. Acid pond bottoms not only do not contribute to the fertility of the water but also deprive it of calcium and other substances. The colloidal content of a soil, especially of the muddy layer on the top, is of importance in its capacity to fix or chemically bind nutrients. The productive capacity of the pond bottom has to be preserved by alternate periods of mud formation and mineralisation. This is the scientific basis of the general practice of regularly draining fish ponds.

POND BIOTA AND THEIR CONTROL

The two main aspects of biotic control practised to increase fish production are the encouragement of the growth of food organisms and the control of biota that are directly or indirectly harmful to the fish crop. It therefore follows that the systems of management will depend largely on the type and size of fish cultivated and their feeding habits. For example, in a pond where plankton-feeding fish are reared the food chain is modified in such a way that the greatest possible quantity of plankton is produced and converted into fish flesh. For the successful cultivation of herbivorous fish, the growth of algae and other suitable vegetation is encouraged. In the culture of omnivorous and carnivorous fishes the food cycle is used to support artificial feeding by the production of natural food.

Phyto-biota

The phyto-biota of a pond consist of bacteria, planktonic and attached microscopic and macroscopic algae and submerged, floating or emergent macrovegetation. The bacterial flora is of special importance as it is essential for the mineralisation of organic substances. The conditions in ponds in tropical climates are favorable for the growth of bacteria if the water is alkaline, and so they are often found in abundance in such environments. They grow floating freely in the water or attached to higher organisms on the pond bed. The mud layer at the pond bottom is also rich in bacteria. The planktonic phyto-biota form the food of the zooplanktonic organisms as well as that of fish and contribute, when decayed, to the formation of the fine colloidal slime or mud on the pond bed. Algal forms like Oedogonium, Spirogyra, Aphanothece, Aphanocapsa, Oscillatoria and Lyngbya may be seen in large or small quantities throughout the year as constant forms in ponds. Other forms are seen for short periods but are not really constant. Even though algae are highly adaptable to environmental conditions, hydrological and climatological changes do affect them to a great extent. Correlated with seasonal changes, fluctuations in the density and the composition of planktonic growths occur. Investigations conducted in India have shown that ordinarily there are two periods of rapid growth in a year, a lesser one in the hot weather and a greater one during the cold weather. The cold season is favorable for the growth and reproduction of a majority of green filamentous forms such as Zygnema, Spirogyra, Bulbochaete and Oedogonium.

Desmids, Chlorococcales and certain Myxophyceae, like Anabaena, occur in abundance during this season. During the hot season most of the desmids disappear and members of Myxophyceae predominate along with numerous Eugleneae. During the period of heavy rains the growth of algae is at a minimum, resulting in a scarcity of phytoplankton in the ponds. The disturbance of water due to wind and rain seems to be inimical to the development of floating vegetable organisms.

The lack of sufficient light for photosynthetic activity and the sudden changes in the concentration of dissolved matter are also limiting factors in phytoplankton production. But during periods of bright sunshine, even in the rainy season, swarms of algae such as Pandorina may occur in ponds.

The macrovegetation of ponds may consist of emergent, submerged and floating plants. Most of the aquatic weeds are large plants, either submerged or floating. Some of the common submerged vegetation of ponds are Nitella, Utricularia, Vallisneria, Potamogeton, Elodea, Myriophyllum, Ranunculus, Chara, Ceratophyllum and Hydrilla. Lotus and Nelumbium are rooted but have floating leaves. Eichhornia may be rooted or floating. Lemna, Wolffia, Azolla, Pistia and Salvinia are common floating plants not attached to the pond bottom. Plants like the reed mace, typha, the burr reed and Sphagnum grow on the margin of ponds or in shallow water. There are also plants like Jussiaea, Enhydra, and Ipomaea which spread to the surface of ponds from the banks.

Submerged vegetation in ponds is normally beneficial to the growth of fish and helps in the maintenance of healthy pond life. Plants are directly eaten by fish or they give shelter to food organisms. They extract inorganic nutrient materials from the soil, from the water or the atmosphere and bring them into the life cycle of the pond. Although plants consume oxygen they also release considerable quantities of it during the day, when carbon dioxide is absorbed and oxygen is given out. Even though accurate determinations of the quantity of oxygen donated by plants by photosynthetic activity have not been made in the region, it is believed that the capacity of tropical freshwater algae in this respect is remarkably high. An adequate growth of plants helps the fish directly by providing the necessary shade during long periods of sunshine. A marginal growth of plants may be beneficial in checking erosion in a pond exposed to wind and wave action. Plants have also a favorable effect on the biological purification of the water in newly fertilized ponds, and many fishes need aquatic weeds on which to deposit their eggs. Thus, controlled growth of vegetation is beneficial, but excessive growths may have harmful effects. oxygen depletion. Green and blue-green algae may grow in such profusion that the pond becomes practically filled with green scum and slime and the pond bed may become carpeted with thick layers of filamentous algae, such as Cladophora, Vaucheria, and Spirogyra. Besides interfering with fishing, such over-abundant growths of algae may result in the creation of abnormal ecological conditions in the pond. For instance, quick utilization of oxygen resources may bring down the oxygen content to a lethal minimum for fish life. In other cases, excessive growths of submerged plants may become noxious as it may lead to biogenic decalcification and an increase in pH. This may be injurious to fish and result in diseases such as fin rot. Thick growths of floating plants cut off light and prevent the growth of valuable phyto- and zooplankton and also hamper aeration. In ponds overgrown with rank submerged vegetation the fish have difficulties in finding their food. Marginal growth of weeds sometimes encourages mosquito breeding and so does floating and emergent vegetation. Predatory fish will hide among the weeds and so the survival rate of cultivated fishes might decrease. Decaying water weeds also often accumulate in such large quantities in the ponds that their mineralisation becomes impossible. These facts show the need for controlling pond vegetation either by biological or by technological means

Control of Algae

The three common methods of controlling aquatic vegetation are mechanical, biological and chemical. Mechanical removal of algal growths is not always successful, although areas can be cleared with nets or screens. The Chinese fish culturists in Malaya prevent over-development of algae by seine-netting the ponds once or twice a week. The algae removed are mashed and fed to ducks and pigs raised close to the ponds. There are few animals that can be confidently recommended for controlling algae in fish ponds. Some snails are algivorous but their efficiency in this respect is very limited. However, plant-feeding fish can be used for the purpose and experiments in Indonesia have demonstrated and experience has proved that Puntius and Tilapia can keep down growths of filamentous algae.

Algae mostly derive their food directly from the water and can, therefore, be controlled by soluble chemicals in the water. Copper sulphate has been widely used in western countries but its effect is only temporary. A weak solution may kill some algae, but stronger dozes are necessary for others. Doses higher than 1 to 2 ppm may be necessary to clear a pond completely but this may be toxic to fish. Copper sulphate has little effect on Cladophora and related species, so to minimize the chances of reinfection, it is advisable to drain off as much of the water as possible before the chemical is applied. A great defect of the method is that the dead algae will decay in the pond and the resulting oxygen depletion might become dangerous to the fish life. It is therefore advisable to give the treatment about a month before the bloom is expected. It is desirable to remove organic debris from the pond bottom and to prevent the entry of other such rubbish.

Control of Macrovegetation

A common cause of rank vegetation is the shallowness of the pond, and a thick layer of mud can also give rise to dense growths of weeds; so by removing the excess of mud from the pond bed, the weed growth can be considerably decreased.

Ducks feed on some kinds of water weeds and a few of them on a pond may help to control their growth, but they can eat the weeds only to a limited depth. Herbivorous fish are very useful and should be used more generally.

Another biological method of controlling the growth of submerged vegetation is to encourage an algal bloom or dense growth of algae by the application of fertilizers. Although efficient, this might deplete the oxygen. Another method is the temporary introduction of a thick layer of floating vegetation, such as water hyacinths, which will completely shade out and thereby kill submerged plants. The method needs very little labor, but there is the possibility of decayed submerged vegetation disturbing the physico-chemical balance of the pond water.

Mechanical removal of weeds and manual cleaning of the pond are the most common control methods in the Indo-Pacific Region. The most efficient mechanical method is to drag them out with grapnels and similar devices. Mowing the pond bed regularly and closely two or three times a year is satisfactory, using a drag scythe, sufficiently heavy to lie on the bottom while cutting. For large bodies of water, a power weed-cutting machine or a power dredge may be necessary. Various other machines, some operated from the bank and others in boats, are used for removal of weeds. Floating vegetation can be mechanically removed either by wading in the water or from boats.

As far as possible, weeds should be removed before they have borne seeds or spores, so that the chances of re-infestation are minimized. Cut weeds should not be left on the pond bed

but should be carried right away from the bank so that spores or seeds are not washed back into the water. In some fish ponds, in Malaya, the weeds are composted with molluscs, worms and insects removed from the pond, and the compost is used as manure for the ponds. Weeds can also be dug into the pond bottom as green compost before refilling.

Chemical Control

It must be remembered that weed-killing substances are often poisonous to fish, to livestock and to human beings. Further, the composition of the water and the properties of the mud must be taken into consideration as they can have an effect on the chemical. In water containing large quantities of dissolved salts, chemical weed killers are less effective and doses lethal to fish may have to be used.

Before treating a pond with weed killers care should be taken to prevent the escape of water to areas in the vicinity which might be adversely affected.

Of the several chemicals that can be used, sodium arsenite appears to be the best. In concentrations of 1 to 2 ppm it kills weeds like Ceratophyllium, Potamogeton and Elodea. Sodium chlorate is satisfactory for killing reeds and other emergent vegetation that grow in shallow pond areas. A $2\frac{1}{2}\%$ solution, sprayed or sprinkled evenly on a sunny day, may kill them completely. The treatment should be repeated after about two weeks, if there is a secondary growth. In ponds where the distribution is made from a boat, the chemical, such as copper sulphate, can be put in a sack and towed around until it is completely dissolved; or a solution of the correct strength can be applied with a spraying machine.

Recent researches have shown that certain plant growth-regulating substances can kill weeds in concentrations which are not lethal to fish life. These are known as herbicides.

The chemical known as 2,4-D is one of these, among others, and is available in several forms under various trade names. An 0.2% solution, applied as a very fine spray at the rate of 1 liter per 3 to 4 square meters will destroy floating weeds in about a month without harming fish. Old dense vegetation, rooted in the soil may, however, need higher concentrations. Herbicides can be diluted by rain or dew, so it is not advisable to spray on rainy or very cloudy days. From experiments conducted in India it was found that 2,4-D can also kill submerged vegetation like Hydrilla and Najas. Even rooted plants like Vallisneria and Nympheae can be killed in about 20 days by spraying the pond surface.

Herbicides must come into contact with the plant leaves to be effective and so it may be necessary to lower the level of water in the pond before spraying. A marked rise of the plankton production has often been noticed after applying herbicides.

The concentrations and rates of application for particular weeds and conditions should be ascertained before ponds are treated with these substances.

Zoo-biota

Zoo-biota in a pond also consist of floating, attached, and bottom-dwelling organisms. Copepods, cladocerans, rotifers and flagellates constitute the main portion of the micro-fauna in ponds. The zooplankton exhibit a seasonal periodicity in their abundance similar to that of the phytoplankton. In ponds with thick deposits of organic matter, and abundance of cladocerans, fewer copepods and a paucity of rotifers is often noticed. On the other hand, eutrophic ponds may contain large numbers of rotifers during hot periods. The zooplanktonic organisms are of great importance in the productivity of fish ponds, as they form the main food of young fish.

Among the macro-fauna of ponds, worms, molluscs, crustaceans and insects are of importance. Oligochaetes, such as Nais, Chaetogaster, Dero and Aulophorus, are found among vegetation or in the bottom mud. Among the crustaceans, prawns and shrimps are common and crabs, like Paratelphusa, are also found. Both the adults and larval forms of insects are frequent in ponds. Mayflies (Ephemeroptera), caddis flies (Trichoptera) and midges (Diptera) are very common forms and they constitute the food of certain fishes. Mosquito larvae are found in most stagnant waters and adult fish and the young of some cultivated species feed on them avidly. Larvae of various species of Chironomids are consumed in quantities by common carp.

Extraneous fish in ponds can be divided into weed fishes and predators. Water bugs, such as Notonecta, Nepa, Ranatra, and beetles, such as Cybister, may become harmful in nursery ponds. Their control is difficult as it is not easy to keep them out or to remove them. A satisfactory method of controlling insects is to spread a layer of linseed or mustard oil on the pond surface. It is practised by a few fish culturists in Bengal and the method was found to be effective in experiments recently conducted in India. The insects are suffocated.

Some of the weed fishes may be useful for checking mosquito larvae, but they also compete with the cultivated fishes for food and their number should, therefore, be kept down to the minimum. To control mosquito larvae in fish ponds, it is better to introduce strongly larvivorous species like Gambusia, Lebistes and Aplocheilus, rather than species that only take larvae in the absence of other food material. Most of the common food fishes fall under the latter category. By stocking a few larvivorous fish and by keeping the pond surface free of aquatic weeds, mosquito breeding can be minimized.

The predaceous fishes are notably inimical to the cultivated fishes in ponds. The murrels (Ophicephalus spp.), the freshwater shark (Wallago), the climbing perch (Anabas) and the cat fishes (Clarias) are probably the most destructive predaceous species in the region. Periodic draining and cleaning enable the fish culturist to remove most of the predaceous fishes, but in ponds that cannot be drained or desilted the chances of their survival are great. The murrels are extremely hardy and, because of their breathing habits, can survive in almost all types of waters. Even in times of drought they are able to survive by burrowing deep down in the wet mud.

To exclude predaceous fishes from a pond, it should be completely drained and desilted before stocking. Great care should be taken while filling the pond to exclude spawn or fry of predaceous fishes. In ponds which cannot be completely drained and cleaned, repeated fishing is the only method of controlling predators. Besides fishing with drag nets and cast nets, longlines can be used, because they can be used regularly even after a pond has been stocked. Similarly, murrel nooses can keep that species under control.

Certain birds, such as cormorants, fish eagles, herons, and kingfishers, feed mainly on fishes. Cormorants in flocks of 20 or more swim in a row on a pond and by flapping their wings, drive the fish into a shallow area where they are eaten. A cormorant is said to eat double its weight of fish daily. Fish eagles, herons and kingfishers also take a heavy toll of fish from ponds, especially when the water level is low. Thin lines stretched across the pond are the most efficient means of preventing their entry.

Otters are extremely destructive of fish and are found both in hills and plains. They bite and kill a great number of fish, but eat only a few. Otter traps can be used to catch them, but proper fencing is the best preventive. Trained otter-hounds on a pond farm eliminate the nuisance.

Snakes, which can cause great losses of young fish, can be caught in baited fish-traps.

PREPARATION OF PONDS FOR STOCKING

Preliminary

The first step in the preparation of a pond for stocking is to check the inlet and outlet arrangements and the embankments. Repairs or improvements are effected if necessary. Undesirable aquatic biota and the correction of the physico-chemical properties of water and soil should also be undertaken if needed. Stocking ponds should, as far as possible, be drained regularly and large accumulations of organic deposits at the bottom removed. Where draining is not possible, excess of organic matter can be collected with long scoops from the banks or boats. If a pond is drained before stocking, predatory fish and other animals can be controlled to a large extent. Where this is not possible, repeated fishing should be done. But for a more efficient control of predators, fish poisons may be used with advantage before stocking. The ponds should be stocked only after the water has become free of all traces of the poison.

Liming

Another important matter in pond preparation is liming. Liming serves a double purpose: it helps in maintaining the sanitation of the pond and also acts as an agent which increases the productivity of the water. Ponds in which there has been a fish disease, or which have acid water or a low alkaline reserve, should be limed before restocking them. Lime, by its toxic and caustic action, will kill bacteria as well as fish parasites and their intermediate stages. The alkaline reserve will be increased and marked fluctuations in the pH will be effectively stopped. Furthermore, undesirable iron compounds in the water will be neutralized and, in acid waters, the pH will be brought to alkaline level. The condition of the soil is greatly improved by liming as it will enhance the process of mineralisation. A reduction of organic matter will also diminish the chances of survival of fish parasites. Liming will reduce the hazards of oxygen depletion and may precipitate the excess of dissolved organic matter and thus lessen the chances for diseases like gill rot. Lime is generally applied in the form of ground limestone, (calcium carbonate), slaked lime (calcium hydroxide) or quicklime (calcium oxide). The calcium carbonate slowly dissolves in the water and is converted into calcium hydrocarbonate. It is of special value in liming light pond bottoms for the purpose of fertilization. Quicklime has the property of binding acids and influencing the pH rapidly, but the process of calcium enrichment and increase of alkaline reserve proceeds more slowly than with calcium carbonate. However, quicklime has the advantage that the same results can be obtained in a pond by the application of only half the quantity.

Lime can be applied on the pond bottom, added to the water at the inlet, or spread on the water surface. Slaked lime and quicklime should as far as possible be applied in ponds after draining. It is desirable to leave the pond dry for at least two weeks after application to take full benefit from the treatment. When lime is applied for controlling the growth of parasites or for the improvement of the pond bottom, the pond bed and not the water should be treated. Only when control of gill rot disease or the precipitation of organic substances is intended, should the water itself be limed. A dosage of about 200 kg of quicklime per hectare is recommended for the purpose, but the quantity applied should be so regulated as to maintain the pH below 10. For a thorough disinfection of a pond, a dose of about 10,000 kg per ha is necessary, but if the liming is regularly done every year for fertilizing purposes, 100 to 200 kg per hectare are sufficient for soils which are not very acid or poor in carbonates. A dressing of 1,000 to 1,500 kg per hectare will be required for ponds with acid soil and water.

The quantity of lime to be applied should be determined with regard to the alkaline reserve as well as to the nature of the pond soil. While about 200 kg per hectare are usually sufficient

to bring the alkaline reserve of water to the desirable level of 1 cc of hydrochloric acid per liter, much larger quantities may be necessary to neutralize the acids present at the bottom. It is necessary to bring the pH of the soil to about 6.5 to prevent a sudden fall of the pH of the pond water.

The calcium requirements of the soil can be roughly determined on the basis of its pH. Schäperclaus (1933) quoted the following table from Trenel, which can be used for estimating the lime requirements of a pond soil when its pH is known.

pH of the soil	Lime requirements in hundreds of kg of calcium oxide per ha		
	Heavy clay or loam	Loamy sand	Sand
more acid than 4	40	20	12.5
4 - 4.5	30	15	12.5
4.5 - 5	25	12.5	10.0
5 - 5.5	15	10	5
5.5 - 6	10	5	2.5
6 - 6.5	5	5	0

Macan, Mortimer and Worthington (1942) recommend the following applications of calcium carbonate to muds of different pH:

pH of mud	Calcium carbonate required in hundreds of kg per ha
Less than 4	60 - 120
4.0 - 4.5	48 - 96
4.5 - 5.0	36 - 72
5.0 - 5.5	30 - 48
5.5 - 6.0	16 - 30
6.0 - 6.5	14 - 16

Another method is by shutting off the pond and applying lime in small quantities until the alkaline reserve reaches 1 to 2 cc of hydrochloric acid per liter.

Fertilizing

There is a continuous consumption of nutrients in a pond to operate the metabolic cycle and, unless the nutrients are regularly replenished, the biological productivity of the pond is necessary for the maximum production of fish. Periodic draining mobilizes the nutrients in the pond soil by exposure to the atmosphere. But in intensive fish culture it is often necessary to apply fertilizing agents to enhance the natural productivity.

As in agriculture, organic and inorganic fertilizers increase production. Cow-dung, pig and poultry manure, spoiled oil cakes, spoiled cotton seed and soya bean meal, compost, sewage, and green grass are commonly used as organic manure in fish ponds to get higher yields. Nitrate of sodium, ammonium sulphate, ammonium superphosphate, muriate of potash and standard mixtures of these materials are used as inorganic manures. Although it is well known that fertilizers can increase fish production, very little is known about the actual mixtures and quantities best suited for particular conditions. Earlier investigations in Germany and experiments conducted in Alabama (USA) by Swingle and Smith (1938, 1939, 1941 and 1942) yielded considerable information on the effect of fertilizers, especially inorganic, under temperate climatic conditions. The fish-carrying capacity of ponds in Alabama was increased by 300 to 400% as a result of fertilizing.

Very few critical investigations on pond fertilizing have so far been undertaken in the Indo-Pacific Region, but there are traditional practices of fertilizing fish ponds with organic manures. The Chinese and the Indonesians build latrines above their fish ponds, or buy night soil to put into them. Letting sewage into fish ponds, as practised near Calcutta and now experimented with in other areas, is a system of organic manuring that has proved to be profitable. Organic manures have the obvious disadvantage that (i) their nutrient values are highly variable, (ii) unless applied under strict control they may give rise to organic pollution and oxygen depletion, and (iii) they induce heavy growths of filamentous algae which might harbor mosquito larvae and pupae.

Preference is usually given to organic manures under tropical conditions because import restrictions limit the supplies of inorganic manures and when available they are relatively expensive, whereas manures, like grass, dung, etc., are usually readily available. Further, organic manures improve the physical structure of the soil, their nutrients are held by the soil for longer periods and so their activity lasts longer. Smith and Swingle (1942) inferred that the effectiveness of manures like cotton-seed meal and soya-bean meal can be increased by the addition of an inorganic fertilizer like superphosphate.

The effectiveness of fertilizers in a pond is greatly influenced by the nature of the pond bottom. If it is satisfactory, in which mineralisation of organic matter takes place rapidly, nutrients are absorbed, held and released slowly over a long period. On such a bottom the effect of fertilizing would last over a year, whereas on a poor one the fertilizers applied are leached out in a short time. Macan et al (1942) classified pond bottoms into the following main types:

(1) Inorganic bottoms of gravel, sand or clay, which are very poor, but can be improved by the application of stable manure or sewage sludge. (2) Peaty bottoms, formed by the accumulation of vegetable debris which has not decomposed, and are therefore barren. The application of large doses of lime may bring about decomposition, resulting in increased fertility. (3) Mud bottoms, composed of a mixture of organic matter of decomposing animals and plants and fine inorganic matter, forming a soft black mud. This is the most productive type.

In view of the importance of the pond bottom in fertilizing practices, a proper study of its composition and defects should be made before adopting a suitable fertilizing technique.

In applying organic manures proper care has to be taken to balance the oxygen budget, and the oxygen concentration should not be allowed to fall to the lethal level, which for most fishes is below 3 ppm. As at present practised, this is done by trial and error. If the techniques are to be standardised, it is necessary to study the constants of different types of water areas and the biochemical oxygen consumption of different types of organic manures. Phelps (1948) mentions that the aeration constant of small ponds in temperate climates is 0.05 to 0.1 per day, but this value will be different in tropical countries, mainly on account of the prevailing temperature conditions.

Ordinarily, a dose of over 1,000 kg of cattle or horse manure per hectare is recommended; when poultry manure is used, about 560 to 1.21 kg per ha is sufficient. These quantities have, of course, to be varied to suit the condition of the soil and water. Where organic manures derived from livestock are not available, compost can be used as a substitute. Any available plant matter, such as leaves, grass cuttings and aquatic vegetation, can be composted in layers of about 30 cm high with 7.5 cm layers of manure between, dusted liberally with superphosphate of lime. Roughly a proportion of 1 : 10 of nitrogen to carbon is necessary for rapid decomposition of vegetable matter. For this purpose 25 kg of nitrate of soda for about 1,000 kg of compost have to be applied and, to maintain the necessary humidity of the compost heap, some 4,000 liters of water will be necessary. The compost should be turned after five weeks and again at eight weeks, and it should be ready for use in about three months. About 5,000 kg per ha may be needed to give rise to a sufficiently abundant growth of fish food in ponds.

The practice of composting green grass with cow-dung and oil-cake in nursery ponds has been referred to, and this is also done in stocking ponds. It is best to apply organic manure after the pond is drained, when it can be raked into the pond bottom. If this is not possible, manure can be heaped at selected spots within the pond in suitable enclosures from where it will slowly diffuse into the water. The chances of water pollution are greatly avoided by this practice.

The important fertilizing elements can be supplied to a pond by applying standard fertilizers such as sodium nitrate, superphosphates and muriate of potash. Fertilizer mixtures are used when there is a deficiency of more than one element. Inorganic fertilizers are generally expressed as percentages of available nitrogen (N), phosphoric acid (P_2O_5) and potash (K_2O). Thus 6 - 8 - 4 (N-P-K) would contain 6% N, 8% P_2O_5 and 4% K_2O. A number of formulae for inorganic fertilizers for fish pond manuring have been evolved; and two of them which have given good results in the USA are given below:

I.	100 kg of 6-8-4 (N-P-K) 10 kg of nitrate of soda
II.	100 kg of sulphate of ammonia 150 kg of superphosphate (16%) 12.5 kg of muriate of potash 37.5 kg of finely ground limestone.

While the ingredients of the first formula can be applied separately or as a mixture, in the latter they are invariably mixed before application. A mixture of organic and inorganic manures, consisting of three parts of animal manure and one part of superphosphate, applied at the rate of about 500 kg per ha per annum, is also quite effective.

It is most desirable to apply and rake the inorganic fertilizers into the pond bed after the pond is drained. Where this is not possible, inorganic manures can be applied from boats or, in small ponds, strewn on the pond surface from the banks. The first application can be made after the rainly season, and in a new pond it should be repeated two or three times at weekly intervals. Later, it will be necessary to apply fertilizers only at intervals of a month or so, or when the water becomes clear. The application of fertilizers causes a bloom to develop and, if the turbidity is such as to make a Secchi disc disappear at a depth of about 45 cm, the pond is considered to be properly fertilized. A rough test is to extend the forearm into the water up to the elbow, and if the fist is not visible, it can be inferred that the pond has been satisfactorily fertilized.

STOCKING PONDS

General Principles of Pond Stocking

The foremost objective in commercial fish culture is the production of a maximum quantity of fish through the most economic management measures. All cultural operations have to be planned with this in view. Even though there are many biological principles that govern stocking procedures, economic factors are so important that stocking methods vary greatly from country to country. For example, some of the Japanese fish culturists feed an almost exclusively artificial diet in quantities that make it possible to stock an incredibly large number of fingerlings per unit of surface. In India artificial foods are very seldom used. The foods that could be given in India are relatively expensive and so stocking methods are devised to utilize to the maximum extent the fish food produced in the ponds naturally or by fertilizing.

To evolve sound stocking techniques the basic information necessary is the food requirement (quantity of food consumed in unit time) of different age or size groups of fish and the quantity of fish food that is or could be produced in the pond. This sort of information is unfortunately not available in the region at present. Until it has been ascertained, stocking systems have to be based on common sense and empirical experience. Based on the expected growth increment of the fish, the total production and the expected mortality figures, the number of fish to be stocked can be computed by the formula:

$$\text{Number of fish to be stocked} = \frac{\text{Total expected increase in weight}}{\text{Expected increase of weight of individual fish}} + \text{Mortality}$$

For example if in a one-hectare pond, a total production of 1,000 kg of carp can be obtained and the pond is to be stocked with 30 g fingerlings, to be harvested when they have attained a weight of 330 g, the expected mortality being 10%, the number of fingerlings to be stocked will be:

$$\frac{1000}{0.3} + 100 = 3433$$

It should be understood that the growth rate of a fish and the total production obtainable are dependent on the environmental conditions. They vary, therefore, from place to place. However, by using the available information, stocking rates can be calculated, which might have to be modified for other areas on the basis of local experience. According to popular belief in India, a mature fish would need about 5 cubic meters or 4.5 square meters of water in a stocking pond for its health growth. Although critical experiments have not so far been conducted to determine the correct quantity of water needed for fish of various species to thrive, the experience of fish culturists in China and Japan has shown that they can do well in much less space, provided

respiratory and nutritional requirements are fully met. The following table shows the space allowed per fish in a stocking pond in some of the countries in the region, where intensive fish culture is carried out:

Country	Surface area of pond in m^2 per fish	Volume of water in m^3 per fish
Malaya	9 - 15.5	13.30 - 20.10
Hong Kong	0.30 - 0.38	0.51 - 0.65
South China	0.94 - 2.00	1.90 - 2.80
Yang Tze Region	1.30 - 1.60	3.30 - 4.10
Japan:		
Stagnant common carp ponds	2	3
Ponds with flowing water	0.03	0.05
Eel ponds	0.02	0.05

The Hong Kong fish farmers provide only 0.30 square meters of water area per fingerling at the time of stocking but after three or four months they start running the stocks and remove all fish weighing over 150 g. A space of 1.3 to 1.3 cubic meters or 0.94 to 2.8 square meters only is allowed in many stocking ponds in South China. The density of stock in some of the Japanese ponds is probably the highest that has so far been attained. Since the oxygen requirements of common carp are not high. Japanese fish farmers stock as many as 86 fingerlings per square meter of pond area but provide flowing water to replenish the oxygen consumed.

An important factor in productivity is the association of compatible species in ponds. Many of the cultivated fishes are extremely selective in feeding habits and so if any one species alone is stocked it would make use of only a part of the food resources. This is obviously not economical. If fish culture is based on an association of species which together utilize all the food produced, a higher yield can be obtained. Species tolerant of each other are generally the most productive associates, but in the USA carnivorous species are added to maintain the population at an optimum level. This is seldom done in the Indo-Pacific area.

Species that have complementary feeding habits or feed in different zones in the natural form very suitable associates. The difference in the feeding habits of the young and adults of certain species of cultivated fishes can also be exploited. For this purpose the ponds are stocked with a suitable number of fish of different age groups. As a natural extension of this practice initially a combination of size groups is stocked in a pond at a high level of population density, and then periodically thinned as the fish grow. Based on these practices, fish associations have been evolved in many countries of the Indo-Pacific Region.

In China, various species of carp with complementary feeding habits are stocked together. The fish culturists of Hong Kong have added the bream and the grey mullet to this association. The fish culturists of Malaya follow the same system, but have often added the tilapia to it. In Indonesian freshwater fish ponds, carps and tilapia are now cultured together. In India and Pakistan catla, rohu, mrigal and calbasu, sometimes with bata, form a common combination. In the State of Madras, pearl spot, gourami and acclimatised milk fish are also cultivated with carps. These are all herbivorous species, but in Vietnam and Japan certain carnivorous fishes are added to the combination. In Cambodia, for example, siluroid and cyprinid fishes are cultivated together.

The omnivorous common carp and the carnivorous eel are stocked together in Japan. The provision of artificial food in sufficient quantities appears to check the predaceous instincts of the eel.

As already pointed out, although the principles underlying stocking operations are essentially the same in the various countries, the details of the techniques vary greatly with the culturable species available and the environmental and other conditions existing in the area. In view of this, the stocking operations followed in the various countries of the region are now described separately.

Pond Stocking in China. An outstanding feature of the Chinese fish farming technique, which has influenced the selection of compatible species, is that artificial feeding is almost a universal practice. Therefore associations have been evolved not only to utilize the fish foods that are produced in the pond but also to use the artificial foods that can be provided.

The fishes usually cultivated together in China are (1) the grass carp which feeds on coarse vegetable matter either present in the pond or supplied; (2) the black carp which feeds on snails and other molluscs either present in the pond or artificially introduced; (3) the big head, which consumes the macroplankton produced in the pond; (4) the silver carp feeding on all planktonic organisms; (5) the mud carp feeding at the bottom on worms and organic matter; and (6) the common carp which is omnivorous and acts as a scavenger.

The fish farmers in Hong Kong have slightly enlarged this association. On account of the scarcity of available carp fry in the colony and the difficulty in procuring fry from the mainland of China, the farmers had to look for locally available species to add to the restricted supplies. The grey mullet, Mugil cephalus, and the bream, Parabramis pekinensis, proved to be quite satisfactory. The grey mullet feeds on organic debris and algae, including diatoms, and also takes rice bran and ground cereals. The bream is described as "mildly omnivorous". This combination of species has proved very profitable and it has now gained in popularity to a considerable extent in the slightly brackish coastal ponds of the New Territories of Hong Kong.

The fish culturists in Taiwan include in their carp ponds the milkfish, which feeds on algal matter, either decayed or growing in the benthic zones. This combination has proved to be satisfactory and gives good yields.

Lin (1954) collated the available information on the different stocking procedures followed in China and his information is summarised below. But it is emphasized that these systems are only those at present practised and found to be profitable and are not necessarily the most efficient. The Chinese systems can be broadly classified into three: (1) the Kiangsu and Chekiang, (2) the West River Regions, and (3) the Hong Kong system.

Stocking in Kiangsu and Chekiang evolved with due reference to the nature of local ponds and the availability of stocking material. Ponds in this region vary in depth from 2 to 7 meters. Black carp, (Mylopharyngodon piceus), is preferred to grass carp because of its greater market value and the fact that pond snails, which form their favorite food, are easily available. The cold climate of the area precludes the culture of mud carp, and common carp is considered an essential fish because of its scavenging habits. In ponds having average depths of 2.5 m the following three systems are generally practised:

Stocking Rate of Ponds in Kiangsu

Species	Length of fish stocked, in mm	Number of fry per ha		
		System I	System II	System III
Black carp	250 - 350	1000	2000	2400
Black carp	150 - 180	2000	200	-
Grass carp	200 - 300	-	2000	-
Silver carp	150 - 200	3000	3000	2400
Big head	150 - 200	600	1600	-
Common carp	150 - 200	200	200	1200
Bream	120 - 150	500	500	-
	Total	7300	9500	6000

The following three systems of stocking are adopted for cultivation of yearlings in deeper ponds, the depth varying from 3 to 7 meters.

Stocking Rate of Deep Ponds in Kiangsu

Species	Wt. of yearlings in g	Number of yearlings per ha		
		System I	System II	System III
Big head and silver carp	500	4500	4500	9000
Grass carp	500	600	-	3000 (*)
Black carp	500	-	450	-
Common carp	200	200	200	200

In Tinghai and Shaoshing in Chekiang, the number of associates is considerably reduced and the proportion of black carp increased. The fishes are usually cultivated for three years. The system of stocking is shown in the following table. During the first year they are reared in ponds 1.3 to 1.5 m deep; in the second year in ponds about 2 m deep, and during the third year ponds of $2\frac{1}{2}$ to 3 m deep are used.

(*) The grass carp is often substituted by an equal number of black carp.

Stocking Rate of Ponds in Chekiang

Species	First year		Second year		Third year	
	Initial wt. in g	No. of fingerlings per ha (age 3 to 9 mths)	Initial wt. in g	No. per ha (age 15 to 21 mths)	Initial wt. in g	No. per ha
Black carp	35	6000	500	1300	2750	240
Silver carp	40	400	600	1000	600	400
Big head	40	400	600	80	600	300
Common carp	30	400	350	50	350	200
Total		7200		1530		1140

By the end of the third year the black carp attain a weight of 5,000 g and the 15- to 21-months-old silver carp, big head and common carp weigh 1,500 g, 2,000 g and 750 g respectively. Mortality during the first two years is about 10% and in the third year the mortality is negligible.

Stocking in the West River Region

In certain regions of South China and in the Tonkin province of Vietnam, belonging to the West River system, the stocking methods are modified to suit local conditions. The climate here is warmer than in Kiangsu and Chekiang and so it is likely that the rate of mortality will be higher. The black carp is therefore given less importance, but mud carp grow very well in the subtropical climate of the region and there is an abundant supply of grass, silkworm wastes and mulberry leaves to feed the grass carp.

Stocking Rate of Ponds in the West River Region

Species	Length of fish in cm	Number of fish stocked per ha					
		Ponds with average depth of 1½ m			Ponds with average depth of 2 m		
		I	II	III	IV	V	VI
Grass carp	60 - 15.0	1200	1200	600	480	1200	2400
Silver carp	10.0	300	240	600	1200	1800	400
Big head	10.0	300	240	1200	510	1800	400
Mud carp	7.5	1800	4800	-	2400	3600	7200
Common carp	5.0	1200	360	3600	-	1200	300
Black carp	5.0 - 10.0	100	24	120	60	-	150
Bream	7.5	-	-	-	600	-	-
Total		4900	6864	6120	5250	9600	10850

Systems I and II are suitable for very fertile ponds in which a good supply of artificial foods can be provided. Systems III and IV are suited to fairly deep ponds when it is not possible to obtain sufficient quantities of fodder for grass carp. In deeper ponds with a good water supply, stocking system V and VI will be the most suitable.

Shallow ponds are also utilized for raising big fish, though they are not so productive as the deeper ones. Fewer fish (about 3,000 to 3,600) can be stocked per hectare in such ponds. The two stocking systems commonly practised for ponds with an average depth of 60 cm are indicated below:

Stocking Rate of Shallow Ponds in the West River Region

Species	Initial wt. of each fish in g	Number of yearlings per ha	
		I	II
Grass carp	50	240	480
Silver carp	20 - 40	1200	972
Big head	100 - 150	120	240
Common carp	0.4 - 0.5	1680	972
		3240	2664

As the water temperature in shallow ponds may become too high for mud carp and black carp in summer, they are not kept in these ponds during the hot period, and even the other carps are stocked only in February/March and removed in the summer. Fish of marketable size (above 500 g in weight) are sold and the smaller ones are transferred to deeper ponds for further growth.

Hong Kong System of Stocking. The distinctive feature of pond stocking in Hong Kong is the use of grey mullet which are abundant in that region. In the coastal ponds with slightly brackish water it is possible to culture various species of carp. Stocking systems that have been found to be profitable for ponds, 1 to 2.5 m in depth, are given below.

Stocking Rate of Ponds in Hong Kong

	Length of fry in cm	Number of fingerlings per ha		
		I	II	III
Grey mullet	2.5 - 4.5	12,000	27,360	15,000
Grass carp	5.0 -10.0	1,524	300	700
Silver carp	7.5	2,208	2,568	600
Big head	7.5	1,536	524	600
Mud carp	5.0	9,600	3,120	9,000
Common carp	5.0	-	-	4,800
Bream	5.0	-	-	-

These systems are modified to a large extent on the basis of personal experience and availability of stocking material. When the mullets have attained a size of about 12 cm the stock is thinned by regular fishing.

Stocking System in Malaya and Thailand. The stocking systems in Malaya and Thailand are to a large extent based on the Chinese systems, but several modifications have been effected to suit local conditions. In both these countries fry other than of common carp have to be obtained from China and the import is restricted due to high prices and transport difficulties. Further, the returns from the culture of mud carp are found to be not commensurate with the expenses and effort involved in bringing the fry from China. On the other hand, plants suitable as food for grass carp are freely available in the area; so the fish culturists in Malaya stock their ponds with proportionately larger numbers of grass carp in association with silver carp, big head and common carp. The ponds are often relatively understocked but, by intensive feeding and fattening, the farmers obtain a satisfactory yield. Utilising the large quantities of food available, the fishes grow rapidly and reach marketable size in a short time so it is possible to raise two crops of fish a year. This ensures satisfactory returns to the farmer. Four typical systems of stocking ponds, 1.2 to 1.5 m deep, are shown below, but, depending on the availability of stocking material and the food resources of the pond, modifications are effected.

Stocking Rate of Ponds in Malaya

Species	Initial weight of each fish in g	No. of fish stocked per ha			
		I	II	III	IV
Grass carp	350 - 600	300	320	375	500
Big head	"	100	120	75	175
Silver carp	"	100	125	75	200
Common carp	30 - 60	145	150	120	250
	Total	645	715	645	1125

Gopinath (1950) reported that the combination of species that gave the best results is grass carp, big head, silver carp and common carp in the proportion of 2:1:1:3.

An improved system of stocking has been developed in Singapore. In this the period of fry rearing (except that of common carp) is extended to about eight months instead of the usual three months, and from the nurseries the fish are transferred to fattening ponds where they are allowed to grow for about six months. The stocking rates commonly followed are shown in the table below.

Stocking Rate of Ponds in Singapore

Species	Wt. in g of fry put into the nursery	No. stocked per ha	Wt. in g of fish stocked in fattening pond	No. stocked per ha
Grass carp	30	1250	1500	450
Big head	40	250	2000	150
Silver carp	40	250	1800	175
Common carp	30	-	-	225
	Total	1750		1000

Stocking Ponds in Japan. The Japanese system of pond stocking is probably the most intensive in the world and the production obtained from some of the ponds is phenomenal. The distinctive feature of the Japanese system is the dense populations of fish reared by intensive artificial feeding. The hazards of oxygen deficiency are overcome by maintaining a constant flow of water and, as the fish increase in size, the populations are thinned out by regular fishing. Common carp and eel are either cultivated in association or separately in freshwater ponds.

Common carp are stocked either in stagnant ponds or ponds having a constant flow of water. In stagnant ponds with a depth of about 1.5 m, one carp of 20 to 50 g weight is stocked for every square meter of water, and in such ponds a yield of 2,500 to 4,500 kg per ha is usually obtained. With adequate water supply and feeding it is possible to increase the yield to 5,500 kg per ha per annum.

The flowing water ponds are constructed as diversions from streams. They are seldom more than 100 m^2 in extent and 1.5 m in depth, a size most suitable for the maintenance of a proper current of water and for efficient feeding. In such ponds carp weighing 56 to 150 g are stocked at the rate of 280,000 to 850,000 per ha. Allowing for a mortality of 10 to 20%, these ponds will yield up to 700,000 per ha per annum.

Eel ponds carry 20 to 44 elvers, 10 to 20 g in weight, per square meter of water. Twenty elvers, about 15 g in weight, per m^2 is a suitable stocking rate for stagnant water ponds. When artificially fed, eels often leave a good portion of the food uneaten. To utilize this food and to act as scavengers, common carp fingerlings, about 7 cm long, are introduced at the rate of one per square meter. When properly fed, about 30% of the elvers will attain a weight of about 120 g in one year and are then harvested. The remaining eels may not have attained that size and a fresh lot (the same number as those harvested) of elvers, about 10 g in weight, are then stocked and allowed to grow for a year. The whole crop is harvested at the end of the second year. A yield of 16,000 kg per ha can thus be obtained with a survival rate of 60 to 90%.

Stocking of Ponds in India and Pakistan. The most important pond fishes of India and Pakistan, catla, rohu, mrigal and calbasu are often cultured in association. Catla feed at the surface zones, mrigal at the bottom and rohu is generally a column feeder. Calbasu is added to this association in certain areas, as it feeds on molluscs. Even though pond culture has been in existence in these countries from very early times it has never been seriously investigated, and it is not yet known what are the most suitable stocking rates. The difficulty experienced in distinguishing the

fry of different species of carps is also a great handicap to proper stocking. It is generally believed that in a stocking pond each carp fingerling should be provided with about 0.1 m^3 of water in the first year, 0.23 m^3 in the second year and 0.45 m^3 in the third year. This is achieved by thinning the populations at the end of each year. Rearing fish after the third year is not profitable as large fish are not relished and do not fetch a good price. Allowances should be made in the stocking system for an annual mortality which may be more than 30%, also for losses by reduction in the volume of water in the ponds as a result of evaporation during summer, which can be computed as about 10%. A proportion of 30% catla, 60% rohu and 10% mrigal is recommended. About 1,875 catla, 3,750 rohu and 625 mrigal, all 8 to 13 cm in size can be stocked in a one-hectare pond. If calbasu is included, the percentage of rohu may be decreased to 50% and the difference made up with calbasu. The mortality rates under present conditions in the ponds are rather high and the actual production is often much lower than should be obtained in view of the high growth rates of these species. As regards the other fishes cultured in India, a stock density similar to that adopted for catla, rohu and mrigal is recommended, even though the optimum rates have not so far been determined. Personal experience has to a large extent influenced the local practices in this respect.

Stocking of Ponds in Indonesia. One of the distinctive features of fish cultivation in Indonesia is that fishes are reared in ponds only for short periods and so several crops are obtained from a pond every year. The preference of local consumers for small fish enables the fish farmers to profit from this. Seldom are fish allowed to grow to more than 200 g in weight. The consumers in rural areas often buy fingerlings of gourami or tilapia and keep them in small ponds or tanks near homesteads, where they are fattened on kitchen waste.

Association of species for the full utilization of food resources is not so highly developed in Indonesia as in China, but the following combination has been tried and found to be suitable:

Common carp	30%
Tilapia	35%
Nilem	20%
Gourami	15%

The methods previously described of stocking common carp in nilem ponds for raising marketable fish have been found to be very satisfactory in Indonesia.

FISH FEEDING AND GROWTH

Foods and Feeding

One of the main factors governing the growth rate of pond fish, and thereby the productivity of a pond, is the availability of suitable foods. The food elements that are produced in the course of the annual biological cycle, and the natural or artificial foods that are supplied, are the two main types of food available to the fish.

Mention must be made of the organic debris, composed of decayed or decaying vegetable or animal matter. Many bottom-feeding fishes depend largely on this and the benthic flora and fauna that grow on them. Organic debris, besides directly forming nutritive food material, gives rise to a good planktonic growth as a result of mineralisation. However, the amount of organic debris accumulating in a pond should be kept under control and regulated in accordance with the requirements of the fish cultivated.

The fish food produced in a body of water is influenced by a variety of factors and so the natural fish production per annum varies from less than 10 kg per hectare to 2,000 kg and more. If artificial feeding is done regularly it is possible to stock ponds with larger populations of fish than they can normally sustain. Three types of fishes are recognised in pond culture: they are (1) those that thrive on artificial foods; (2) those that thrive best on a diet composed of both artificial and natural foods; (3) those that take only natural food and do not relish artificial foods. Grass carp, black carp and eel are examples of the first group; common carp, mud carp, catla, rohu and mrigal belong to the second group; and big head and silver carp to the third group. In selecting food for fish, the dietetic values as well as the economic practicability of using them have to be taken into consideration.

The ratio of food consumed to the fish flesh produced is known as the forage ratio. The term food quotient, expressing the unit weight of fish food required to produce unit weight of fish flesh, indicates the relative value of fish foods. The food quotient is determined by dividing the weight of the food consumed by the fish's total weight increment. The food quotient of a species of fish is not constant and may vary considerably, depending on such factors as temperature, oxygen content of the water, size of the fish, feeding habits, and general condition. It has been found that the consumption of food increases directly with the increase in temperature of the water in which the fish lives. It has also been observed that the food quotient falls with an increase in the oxygen content of the water. Because the amount of food required for the maintenance of normal life is relatively more in a larger than in a smaller fish, it is possible that the food quotient of the different size groups of fish varies, although this does not appear to have been conclusively proved. Climatic factors and the health condition of fish greatly affect their feeding activity. However, the food quotients often cited are useful for judging the food requirements for normal weight increment. While the food quotients of some of the artificial foods have been determined, the exact dietetic requirements of the pond fishes of the region are not at all well known. Even though an artificial food may be eagerly eaten, the quantity of flesh that will be ultimately produced, and the net profit, has to be considered. It is therefore necessary that artificial foods should be relatively cheap in price. For example, the fish farmers of Japan feed carp, eel, trout, etc., with small fish or fish meal, and in spite of the fact that the forage ratio is high, the industry is profitable because of the high price of cultivated fish and the easy availability and low price of the foodstuffs. But this practice is hardly feasible in other areas of the region where the food material may cost as much as, if not more than, the fish flesh they would contribute to produce.

The food requirements of a fish are often judged by what is known as the sustenance ratio, which is the ratio of the crude protein and the nitrogen-free components, such as fat and carbohydrates, required for the catabolic activity of the fish. The sustenance ratio of fishes varies greatly with age. For example, for common carp in the first year of its life the ratio is 1:0.4 to 0.5, in the second year 1:0.7 to 0.8, and in the third year 1:1.00 to 1.25. Younger carp need a larger percentage of proteins and the older ones a larger percentage of nitrogen-free carbohydrates, (Fujida, 1933). According to Schäperclaus (1933), cultivated fish can be broadly divided into three categories: (1) those with a low sustenance ratio of the order of 1:2 to 1:4; (2) those with a medium ratio of about 1:5 to 1:6; and (3) those with high ratios of 1:8 to 1:12. Trout, as a cold water fish, comes under the category of fish with a low sustenance ratio, common carp comes under the medium ratio, and the grass carp has a high ratio.

A satisfactory means of judging the efficiency of foods is by comparing the food quotients. The selection of artificial foods should be based on this information.

The food quotients of some of the artificial foods are listed below (Shih, 1937; Chen, 1935):

	Food Quotients
Fresh silkworm pupae	5.5
Dried silkworm pupae	1.66
Pressed dry silkworm pupae	1.40
Soyabean cake	2.22
Barley	2.60
Rice bran	5.05
Wheat bran	4.22
Peanut cake	2.13
Spirodela polyrhiza	27.77
Panicum crusgallii	13.33
Cynodon dactylon	11.90

From the above it will be seen that pressed dry silkworm pupae is a highly efficient food, but the economic aspects of its use have to be taken into consideration. The method suggested by Fujida (1933), which consists of expressing the nutritive value of a food in terms of carbohydrates by multiplying the protein and fat values by two and thus arriving at the total carbohydrate values, is useful to some extent in determining this. The total carbohydrate values of foods can be easily compared and equated against their market values to ascertain the economics of using them.

The foods that can be directly provided by the fish farmer consist of the natural foods he collects from other waters and the artificially prepared foodstuffs. Fish show a preference for natural foods and pond fish generally thrive best when natural foods are included in their diet.

Aquatic plants are often used when they are readily available in the vicinity and grass is commonly fed. The composition of common varieties of land grasses and aquatic weeds fed to pond fish is given below (Chen, 1935, Birtwistle, 1931 and Wu 1940):

Composition of Fresh Vegetable Fish Foods

	Water	N %	Crude protein (n x 6.25) %	Crude fat %	Carbohydrate %	Fiber %	Ash %	Sustenance ratio *
Land grasses								
Cynodon dactylon								
fresh	77.6	-	4.89	0.78	10.40	4.17	2.00	1:2.5
dried	-	-	21.99	3.51	46.76	18.75	8.99	
Panicum crusgallii								
fresh	84.28	-	3.65	0.76	6.43	3.43	1.55	1:2.2
dried	-	-	23.22	4.83	40.26	21.82	9.87	
Aquatic weeds								
Duck weed (Spirodela polyrhiza)	94.37	-	1.62	0.02	2.85	0.35	0.79	1:1.8
Wolffia arrhiza	93.46	0.39	2.44	-	1.78	0.73	1.59	1:0.7
Plankton								
Microcystis	93.36	0.53	3.31	0.27	1.81	0.23	1.02	1:0.8
Pond debris	92.07	0.63	-	0.12	-	-	23.16	-

* The sustenance ratio is derived by the formula: $\frac{\text{crude fat} \times 2.2 \text{ carbohydrate}}{\text{crude protein}}$ (Kellner, 1929; Schäperclaus, 1933)

Other aquatic plants like, Cyperus, Ceratophyllum and Elodea, are also suitable for grass carp ponds.

Grass carp, Puntius javanicus, Tilapia mossambica and a few other pond fishes will eat some of the higher plants. About 10 to 15 kg of grass will produce one kg of grass carp flesh. On this basis, the total quantity of grass required to achieve a certain production in a given period of time can be estimated, and this quantity should be given in suitable amounts during the period of rearing. Generally speaking, the grass carp should receive fresh grass at the rate of 10% to 15% of its total estimated weight when grass is the only food provided, usually in the morning and evening when the water is cool. The grass is fed as soon as it is cut, before it wilts. Tender grass grown on fertile land is the best. It is not advisable to throw the grass, or for that matter any food material, indiscriminately into a pond. The usual practice is to construct a special feeding enclosure into which the food is put. In a pond of about 0.5 hectares one enclosure, about 4 m^2 should be sufficient; more in larger ponds.

In the absence of sufficient quantities of natural foods it will be necessary to provide the fish with artificial foods, so as to achieve the maximum rate of growth. Artificial foods are of vegetable or animal origin and the choice depends on the feeding habits and the possibility of training the fish to take the particular food. Fish such as the common carp, grass carp and gourami can be fed on a variety of artificial foods, whereas fish like black carp require a special diet. The composition of some of the artificial foods available in the region is shown in the following table.

Composition of Artificial Fish Foods

	Water	N %	Crude protein %	Crude fat %	Carbohydrate %	Fiber %	Ash %	Sustenance ratio
Peanut cake	12.77		31.82	9.01	27.99		16.89	1:1.5
Soyabean cake	15.86		37.03	9.43	28.03	4.81	4.84	1:1.3
Soyabean milk	91.80		4.40	1.80	1.50	-	0.49	1:2.0
Bean meal	13.62	7.0	43.75	7.56	26.91	4.15	4.01	1:1.0
Barley	13.03	-	10.29	2.17	66.34	5.81	2.36	1:7.0
Flour	14.85	2.40	15.00	0.64	69.05	-	0.46	1:4.7
Wheat	13.59	-	13.07	1.96	63.61	3.91	3.85	1:5.2
White wheat flour	12.80	-	10.80	1.10	74.60	0.20	0.50	1:7.1
Wheat bran	10.50	-	13.90	4.20	55.60	10.50	5.30	1:4.6
Rice bran	9.15 - 11.20	-	13.24 - 15.80	4.30 - 16.05	42.65 - 47.40	6.50 - 6.63	13.28 - 14.80	1:3.6 - 1:5.9

Rice bran or a mixture of rice bran and fine particles of broken rice are very popular fish foods, relished by grey mullet. The different kinds of oil cakes (the residue left after the oil has been pressed out from peanuts, mustard seeds, soyabean, linseed, coconut and the like) are good foods. These cakes should either be powdered or soaked in water before being fed to fish. Starchy foods, such as tubers, should be cooked, not fed in the raw state. Rice bran can either be scattered over the entire pond surface or spread in a feeding frame of the type described above. In mullet ponds it is better to put the bran in bags or baskets submerged in the water at different spots. Oil cakes and similar foodstuffs can be fed in a similar manner. This enables the farmer to assess correctly the quantity of food the fish are actually consuming and to remove all the food left over, which might decay and pollute the pond water.

Artificial foods of animal origin are particularly suitable for omnivorous and carnivorous fish. The commonly used ingredients are fresh and dried silkworm pupae, fish meal, snails and other shell fish, weed fish, shrimp wastes, slaughterhouse refuse, cow dung, pig and poultry manure, silkworm wastes and night soil. The composition and sustenance ratios of some of these foods are given as follows:

Composition of Fish Foods of Animal Origin

	Water %	Crude protein %	Crude fat %	Carbohydrate %	Fiber %	Ash %	Sustenance ratio
Fresh silkworm pupae	64.63	19.12	12.75	2.33	-	1.16	1:1.6
Dried silkworm pupae	10.03	55.91	24.50	5.58	-	2.98	1:1.1
Defatted silkworm pupae	8.90	75.36	1.75	8.40	-	5.59	1:0.2
Flesh of other snails	75.76	19.10	0.55	-	-	4.59	1:0.07
River snail (whole)	36.80	5.70	0.70	2.00	-	1.70	-
River snail flesh	78.40	12.20	1.40	4.30	-	3.70	-
Mussels	79.60	18.40	0.80	-	-	1.20	1:0.09
Small clams	84.04	13.20	0.77	-	-	1.96	1:0.1
Small shrimps	17.20	55.45	5.52	4.37	-	17.65	1:0.3

Fresh or dried silkworm pupae, rich in proteins and fat, are an important fish food in China and Japan, where they are available in considerable quantities. In Japan, common carp and eel are fed on silkworm pupae, and in China they are given to the grass carp and common carp. A daily diet of three pupae is considered sufficient for a grass carp weighing about 600 g. Since the pupae contain a high percentage of fat, it is necessary to reduce the daily ration or even stop feeding altogether during hot periods. The pupae should be as fresh as possible, because tainted pupae can cause serious diseases and also impart a bad taste to the fish flesh. The pupae are generally thrown into the pond. To balance the diet, grass or other vegetable matter should be included.

To store the pupae for later use, they can be cooked and dried. The keeping quality can be considerably improved by extracting the fat. Dried pupae can be thrown to the fish but they are usually mixed with wheat flour and powdered soyabean cake.

Fish of inferior quality can be used as food for common carp, grass carp and catfish, chopped into small pieces and mixed with silkworm pupae and vegetable foods. Sardines and certain species of mackerels, which are available in large quantities in certain periods of the year, are used in Japan as food for eels, either fresh or dried. Fish meal being relatively expensive in the region, few fish culturists use it, except in Japan, where it is sometimes cooked with such materials as wheat flour and rice meal. In some of the fishing centers where large quantities of shrimps are dried and shelled, shrimp wastes in the form of shells and small broken pieces of shrimp meat are available; these, when mixed with wheat flour, corn meal or other vegetable matter, make a very good food for pond carps.

Freshwater snails and mussels are relished by black carp, common carp and grass carp. While black carp can be fed on whole live snails and mussels, the meat alone should be used for the other carps. Since snails and mussels might have parasites, it is essential that only cooked meat be given. All food not eaten should be removed without delay.

Slaughterhouse refuse of different types is given, either fresh, dried or powdered, to trout, eels and carps. It is advisable to mix it with cereals and vegetables for carp.

Farmyard manure, when applied to a pond, is to some extent eaten directly by the fish and the rest helps to increase the fertility of the pond, thereby giving rise to a bloom of planktonic or benthic growth. Since night soil might spread infectious diseases it should not be used in ponds stocked with marketable fish.

Climatic, seasonal and environmental adjustments in feeding

The climatic conditions prevailing in an area have to be considered in arranging feeding procedures. As already mentioned, water temperature has a great influence on the feeding activity of fish. In subtropical climates, when the temperature drops below 15°C in winter, the feeding activity is lowered or entirely stopped, and, until the temperature rises again in the spring, the fish do not resume feeding. The feeding should therefore be scheduled accordingly. Similarly, it has been observed in some cases that when the water temperature rises above 25°C, the feeding activity decreases.

Besides marked alterations in feeding activity there is a less conspicuous seasonal fluctuation in the nutritional and physiological rhythm of fish. The growth rate also varies according to this and so naturally do the food requirements.

In the Kwangtung delta of China, a thickly populated area, grass is scarce but silkworm pupae can be had in good quantities. The ponds being well fertilized, silver carp, big head, mud carp and black carp get sufficient food from the pond itself and only the grass carp need intensive feeding. A schedule followed in the area for feeding grass carp and to some extent common carp and mud carp is given below.

Feeding Schedule for Grass Carp in Kwangtung, China

Months	Approx. mean temp. °C	Percentage of fish growth and food consumption %	Estimate wt. of fish in pond		Quantity of food required per month in kg			
			Wt. increment per month in kg	Total Wt. in kg	Grass	Silkworm waste	Fresh silkworm pupae	Rice bran
February	15			70.00				
March	16	6	127.80	197.80	1534	1022	639	639
April	20	7	149.10	346.90	1739	1193	745	745
May	24	9	191.70	538.60	2301	1534	959	959
June	28	12	255.60	794.20	3067	2054	1278	1278
July	30	15	319.50	1113.70	3834	2556	1598	1598
Quantity harvested at the end of July				800.00				
New stocking material added				200.00				
Stock				513.70				
August	31	20	426.00	939.70	5112	3408	2130	2130
September	28	15	319.50	1259.20	3834	2556	1597	1597
October	27	7	149.10	1408.30	1789	1193	745	745
November	23	5	106.50	1514.80	1278	852	533	533
December	16	4	85.20	1600.00	1022	682	426	426

In the absence of foods shown in the table, others can be substituted, but grass should always be included in the diet. Assuming that the food consumption is directly proportional to the rate of growth, the food requirement for each month is calculated by multiplying the monthly weight increment by the food quotient of the particular food. A feeding schedule can thus be drawn up for any locality and for any species of fish, if the temperature and the growth rate of fish during each month are known. As an example, a general schedule for black carp is given below. It should be stressed that it will be necessary to alter the feeding procedure if the fish do not consume the whole of the daily ration, or if there is any abnormality in their behavior.

Feeding Schedule for Black Carp

Month	Wt. increment kg	Total wt. kg	Wt. of food to be given in kg			
			Mussels	Barley	Bean cake	Total
April	-	450	small quantities	small quantities	-	-
May	155	605	800	-	140	940
June	344	949	1000	634	-	1634
July	937	1886	5000	1000	-	6000
August	937	2823	5000	1000	-	6000
September	376	3199	1880	-	376	2256
October	376	3575	1880	-	376	2256

Small quantities of artificial foods can be given to black carp by the middle of April, but intensive feeding is done from May to October, when the water temperature is around 20°C. In May and June, when it is relatively cold, they can be fed with mussels and snails alone, which are foods of low sustenance ratio. In later months the fish need to be given a diet consisting of half vegetable and half animal foods.

The climatic conditions in Japan necessitate a different system of feeding. Even though light artificial feeding can be done and some results in the way of noticeable increases in the weight of fish can be attained during cold months, the most suitable temperature for feeding carp in Japan is around 24° to 25°C. At temperatures below 7°C, the fish become quiescent and remain at the bottom of the pond in a state of hibernation. Under these conditions feeding starts by about the middle of April and intensive feeding is done from July to early September, after which it is slowly decreased and completely stopped by the middle of November. The following is a schedule for feeding the common carp in such a climate, as adopted by Lin (MS) from Shih (1937).

Feeding Schedule for Common Carp in Japan

Month	Monthly feeding rate in % of total annual quantity	Essential foods	Daily feeding frequency	Time required to finish food at each feeding
January	Nil			
February	Nil			
March	Nil			
April	1	wheat, snail, pupae, soya-sauce waste, earthworm, rice bran	Once a day	Within 1 hour
May	4	mixed foods	Once increasing to 3 times	30 minutes
June	15	pupae as staple foods; and also mixed foods	3 to 6 times	15 to 30 mins.
July	20	silkworm pupae	3 to 7 times	ditto
August	30	ditto	5 to 9 times	ditto
September	20	ditto	5 to 7 times	ditto
October	9	pupae, wheat, bean meal, vegetable and fish meal	2 to 5 times	
November	1	ditto	Once daily, to once every 2 days	30 minutes
December	Nil			
	100%			

This schedule is modified according to the daily weather conditions. On stormy days with heavy showers and strong wind when the temperature falls very low, either the feeding should be stopped or only a little food given. On a sunny warm day the ration can be somewhat increased.

The feeding should be much more intensive in ponds with running water and large stocks of fish. From May to June they are fed once every hour or two, or six times during the day. From July to September the feeding is increased to 12 times a day. In October and November they are fed only six times a day at intervals of two hours. During summer, which is the period of rapid growth, feeding should be done more often in the morning or evening, even up to as late as 9 to 10 p.m.

The feeding schedule for eels in Japan is similar to that of carp. Feeding is done from about March to November and a quantity of food weighing from 5 per cent to 10 per cent of the weight of the fish may have to be given. However, much depends on the behavior of the fish and the experience of the farmer.

Fish Growth in Ponds

The growth of fish is influenced by a variety of factors. The genetic characteristics of the stock themselves are of importance, and this has been well recognised in the cultivation of the common carp. Chinese and Indonesian fish culturists therefore select the quickest growing, fat and healthy specimens for breeding purposes since experience has shown that the offspring of such stock grow more rapidly and yield better.

The rate of growth is directly affected by temperature and other physical conditions of the water. The lowering of feeding intensity or the non-availability of certain types of food affect growth considerably. While a fish will be able to survive in a stunted form when fed on an austerity diet, that is just sufficient for the maintenance of its life, a richer diet is necessary for its rapid growth. The density of the fish population in a pond is therefore a very important factor which influences the growth rate, because it determines the degree of competition in feeding and consequently the amount of food available per fish. The growth of fish is much quicker in understocked than in overstocked ponds. In view of the fact that several environmental and other factors affect the growth rate, it is rather difficult to judge with accuracy the normal or even the maximum growth that can be expected for a species. Data regarding the weights attained by some of the important cultivated fishes are given in the table below. While this should help to form some idea of the comparative growth rates of the species, it is emphasized that these figures are based only on observations; they are not the results of controlled experiments.

Growth Rate of Fishes in Ponds in the Indo-Pacific Region

Species	Weight increment in g during			
	1st year	2nd year	3rd year	4th year
China				
Grass carp	225-680	1200-2300	2700	4800
Black carp	600	2750	4500-5000	9000
Big head	150	900	1800	4200
Silver carp	150	900	1800	3600
Mud carp	75	3300	600	-
Common carp	300	900	1500	2100
Bream	75	450	900	-
Grey mullet	300	1200	2000	
Malaya and Thailand				
Grass carp	1500	3000		
Big head	2000	4500		
Silver carp	1800	4500		
Common carp	400	800		
Philippines and Indonesia				
Tilapia	450-850			
Gourami	120-450	450-680	2400	3800
Belinka	675			
Lampai		2000		
Nilem	350			
India and Pakistan				
Catla	1125-4100	4000-5000	6750	
Rohu	900	3600	5400	
Mrigal	650-1800	2600	4000	
Calbasu	450			
White carp	330			
Cauvery carp	300			
Nagendram fish	700			
Sandkhol carp	900-1400			
Copper mahseer	112			
Carnatic carp	113			
Tench	113			
Cock up	1500-3000	5000		
Indo-China				
Cat fish (*Pangasius larnaudi*)	-	1000		
Cat fish (*Pangasius sutchi*)	-	4000		
Japan				
Common carp (stagnant ponds)	375	927	1980	2300
Common carp (ponds with running water)	350-2400			
Eel	10-120	110-120		

POND MANAGEMENT

Pond Sanitation

It is well known to aquatic biologists that ponds or other bodies of water are able to maintain themselves in a sanitary state under natural conditions. The biological processes that operate under normal conditions rapidly mineralize all dead organic matter, restoring the nutrient cycle which sustains the pond flora and fauna. The oxygen utilized by the fauna and flora is replenished from the atmosphere and the oxygen released by the carbon dioxide assimilation of plants. The free carbon dioxide produced escapes into the atmosphere. But when the pond is used for intensive fish culture, which involves manuring, heavy stocking, etc., the normal biological processes are interfered with and abnormal hydrological conditions may develop. It therefore becomes essential for the fish culturist to keep a vigilant watch on the pond sanitation so that the fish he cultivates will not be affected by the artificial environment created.

One of the main factors to be watched is the gaseous content of the water, especially of oxygen and carbon dioxide. When a pond is heavily stocked with fish there is a rapid consumption of oxygen and, unless there are special means of replenishment, conditions may become unfavorable for fish life. This is the reason why Japanese fish farmers maintain a constant flow of water in heavily stocked ponds. Letting in fresh, oxygenated water at suitable intervals is essential in such ponds to prevent mortality due to asphyxiation. By cascading the water into the pond, its oxygen content can be increased. Regular netting of the pond is often recommended as a means of aerating pond water, but this has to be done cautiously because the organic matter at the pond bottom is otherwise likely to be stirred up; instead of improving the oxygen content, the disturbed organic matter would use up large quantities of oxygen. Under certain meteorological conditions the putrefaction cycle might assume abnormal proportions and affect the pond sanitation. This happens where there is an accumulation of decaying organic matter. In cloudy, sultry and humid weather, absence of rain and wind, the putrefaction of organic matter is accelerated and due to the absence of sunlight the photosynthetic activity of plants is arrested. The putrefaction processes make a heavy demand on the oxygen and the oxygen budget becomes unbalanced. When there is a thick bloom of algal growth in a pond, similar conditions may result. In such circumstances treatment with an algicide, such as copper sulphate, will reduce the algal growth and bring back the pond life to a normal condition. When the oxygen content of the pond becomes low, the fish often come to the surface gasping for breath. The hunger for oxygen also drives other animals to the surface and bottom-dwellers like molluscs to the sides of the pond. Injudicious manuring of ponds would also give rise to the same condition. Mortality due to asphyxiation often takes place under such conditions. The fish culturist has to prevent the development of the above-mentioned conditions, which do not occur in regularly desilted and drained ponds.

Since very dense growths of aquatic flora give rise to abnormal hydrological conditions it is necessary to check them adequately. But once insanitary conditions have developed, suitable eradicatory measures should be undertaken immediately, otherwise the whole fish population will die in a short time. A chemical examination of the pond water is of great help in diagnosing the immediate cause of abnormal fish behavior. Oxygen deficiency is usually the cause of mortality and the best method of rectifying this is to add well-aerated fresh water from any nearby source. Besides increasing the oxygen content of the water this will have the immediate effect of diluting the noxious substances produced in the pond by putrefaction. If the water in the pond can be agitated without stirring up the organic deposits the water can be considerably oxygenated. A portable pump should be kept ready at every pond farm to spray the water and thereby agitate it, in case of emergency.

If the water becomes acid due to putrefaction it can be treated with lime in concentrations of not more than 10 ppm. Should the water become very foul, potassium permanganate can be used in doses not exceeding 1.5 ppm. Besides adjusting the pH of the water this chemical will kill fish parasites and also control excessive bacterial growth. Ordinary washing soda, crude potassium carbonate and wood ash are also useful in reducing acidity; but the optimum concentrations of these materials have not yet been ascertained. Fish farmers in Bengal often cut up banana plants and float them in the water, or extract the juices beforehand and mix them in the pond. Although banana stem juice is acid in reaction (pH 5.2 to 5.7) it contains a considerable alkaline reserve and its buffering action might control fish mortality.

When the generation of noxious gases in pond bottoms becomes excessive, they can be smelt and will ignite and produce high flames on the whole pond surface. Indian fish farmers prevent accumulation of such gases by raking the pond bottom.

High water turbidity due to suspended silt can cause serious fish mortality. The silt chokes the gills and also depletes the dissolved oxygen in the water. Protecting the ponds against dust is helpful in preventing this. Very small doses of alum might help to settle the suspended matter.

Exposure to very low temperatures might cause mortality but this is comparatively rare in the Indo-Pacific Region, except in the subtropical areas of Japan, Taiwan and Central China. In Japan the farmers transfer fish, especially common carp, to wintering ponds, when the temperature of the water drops to zero. A wintering pond of 1 m^2 in area and 3 m deep will sustain 20 to 25 kg of carp during the winter months.

Besides directly killing fish, deterioration of water conditions in a pond may render the fish highly susceptible to parasitic attacks and other diseases. The vigilant farmer can easily detect abnormalities in the water and quickly take remedial action.

FISH DISEASES AND THEIR CONTROL

Fish are prone to hundreds of parasitic and nonparasitic diseases, especially when grown under artificial conditions. Adverse hydrological conditions often precede parasitic attacks, as the resistance of the fish is thereby lowered. Mechanical injuries sustained by a fish when handled carelessly during fishing or transport may also facilitate parasitic infection.

The prevalence of fish diseases is very much dependent on the intensity of stocking. Diseases are more common in China than in India, Pakistan, and other countries where the density of stocking is relatively low. So, when a farmer decides to raise the stocking rate, he has not only to provide extra food, but also to take special care to prevent and cure outbreaks of diseases. Diseases are more common in freshwater environments, and it has been found that susceptible freshwater fish are significantly free from disease when grown in slightly brackish water.

Well-kept and properly managed ponds usually remain free of disease. Carelessness in stocking and feeding may result in serious parasitism and mortality. Prevention is better than cure. Care should be taken to prevent parasites gaining access from a nearby infected source. Even though several curative methods are available, treatment is difficult and often impracticable in ponds containing a large number of fish. Preventing the spread of the disease by quick removal and destruction of infected fish is probably the most effective method of control. Disease-resisting fish should, as far as possible, be selected for stocking.

Some of the common diseases of fishes are described below.

Dysentery. One of the most common non-parasitic diseases is dysentery. Feeding with tainted or indigestible food containing too much fat or protein may lead to this disease. Intensive reddening of the rectum and profuse quantities of yellowish mucus in the gut are noticeable symptoms. The only remedy is to stop feeding, especially with animal food, for a suitable period. Draining the pond and letting in fresh water will help the fish to recover quicker.

Gill Rot. Among the fungal parasitic diseases, gill rot is fairly common among cultivated fishes in the Indo-Pacific Region. It generally occurs in ponds where there is an abundance of decaying organic matter and is caused by the fungus, Branchiomyces. It is often common in summer, especially after a period of hot days. Some of the gill filaments, particularly the upper ones, become blackish red in color and the rest whitish as a result of the penetration of fungus which obstructs the blood vessels. The disease becomes epidemic and causes rapid mortality especially in the early stages of the outbreak. Within about eight days the attack subsides. Some fishes may survive and their affected gill filaments may slough off and then heal gradually. When there is an attack of gill rot in a pond the following measures are recommended: (i) introduce cool water, (ii) prevent undue turbidity of the water and organic pollution, (iii) discontinue feeding, and (iv) add lime to the water. In serious epidemics, if possible, the fish should be netted out and the pond water completely changed before putting the fish back.

Saprolegnia Infection. The fungus Saprolegnia attacks fishes that have sustained mechanical or other injuries. For example, they attack the gill filaments affected by gill rot. Tender parts of the body are more susceptible and so the gills are more commonly affected than the skin, fins, mouth and eyes. When it settles on the body, the fungus sends mycelial branches through the epidermis into the inner layers of the skin causing general disturbance of the system and ultimate death. Saprolegnia often attacks eggs and hatchlings and this may cause serious mortality in hatching ponds. Over-abundance of algal growth, mechanical injuries, over-crowding and fouling of water are considered to be the factors that encourage the attacks of this fungus.

While it is possible to treat individual fish by gently rubbing the affected portions with cotton wool soaked in a 1:100 solution of iodine or potassium permanganate, the most practicable way of treating a large number of fish is by giving them a bath in a 3 per cent solution of common salt, or in a 1:2000 solution of copper sulphate, or in a 1:1000 solution of potassium permanganate, for 5 to 10 minutes or until they show distress. All the affected fish from a pond can be removed in small lots in a hand net and dipped into the solution. Where facilities exist, it is advisable to transfer the fish into a separate small 'hospital pond' where they can be properly treated with chemicals. As with other parasitic fish diseases, it is always desirable to drain the pond and treat the bottom with lime or other sterilizing chemicals.

Fin Rot. Fin rot, or tail rot as it is sometimes called, is caused by a rod-shaped bacterium which grows on the fins. The fins lose their rays and become reduced to a stump. The first sign of this disease is the appearance of a white line along the outer margin of the fin which slowly spreads towards its base until the whole fin is destroyed. This disease is often fatal to younger fish.

The best treatment for fin rot is a bath for one or two minutes in a 1:2000 solution of copper sulphate, which should be done by a skilled person who adjusts the period of treatment according to the behavior of the fish. The treatment should be stopped as soon as the fish shows signs of distress.

Ichthyophthirius Infection. A common protozoan parasite that attacks pond fishes. The infected fish develop small white pimple-like growths on the gills, body and fins. The parasites are about 1 mm in diameter and ovoid or spherical in shape. When they reach maturity they drop off the fish and each divides into about a thousand and are seen as swarms in the pond. They then attach themselves to new hosts, especially young fish. Disinfection of the pond with salt or quick lime is the most effective method of controlling the epidemic. The fish can also be treated with a 3 to 5 per cent solution of common salt for 30 minutes, or a 5 per cent solution of aluminum sulphate for about 1 minute, or a 1:2500 solution of formalin for 15 minutes. If the fish are kept in a live cage and a current of water is passed through it, the parasites will fall off and be carried away by the flow of water. The fish will then recover within two or three weeks. This treatment is not practicable in all ponds.

Cyclochaeta. This attacks the body, gills and fins. It has a flattened ventral side, by means of which it attaches itself to the surface of the fish. In the early stages of the disease, a bath in a 1 per cent solution of salt for 5 to 10 minutes will be sufficient to kill the parasites. In serious attacks, treatment with a 3 per cent solution of salt or a 1:500 solution of glacial acetic acid may be necessary. The best treatment is a bath for 10 minutes in a 1:2500 solution of formalin.

Costia Necatrix. This parasite is microscopic but can be detected by the appearance of a light bluish or greyish film over the body and the fins. The fish stop feeding and become very weak and die in a short time. A bath for about 10 minutes in a 1:2500 formalin solution will kill most of the parasites. A 1:500 solution of glacial acetic acid will also be effective.

Carp Lice. The attack of the carp louse (Argulus foliaceus), a parasitic copepod, is a very common cause of fish mortality in ponds. The louse is oval in shape with a flattened body and small bilobed abdomen. It attached itself by means of a pair of disc-like suckers, on the ventral side of its body, to the skin at the base of the scales. The scales subsequently fall off, exposing the body. The males attain a length of about 6 mm while the females reach a size of about 8 mm. At the time of breeding the louse leaves its host and lays eggs on stones and twigs. The nauplii that hatch out resemble the adults and immediately swim out in search of hosts on which they attach themselves. If a suitable host is not found within three weeks they die.

In about six weeks it attains maturity and is able to reproduce. It sucks the blood of the fish, the infected fish becomes restless and the exposed skin is subject to fungal and bacterial attack. Young fishes succumb to the attack more easily than the adults. The lice leave the host as soon as it dies.

The most practicable way of treating a pond infected with the lice is to remove the fish as quickly as possible, drain the pond and expose the bottom to the sun for at least 24 hours. This kills eggs as well as adults. Where draining and drying are not possible, lime applied at the rate of 0.1 to 0.2 g per liter is often effective. As the parasites die within three weeks in the absence of a host, it is not advisable to restock the pond until that period has elapsed.

Schäperclaus (1953) recommends a lysol bath as a treatment. The fish, caught in a basket or dip net, should be immersed in an 0.2 per cent solution of lysol for a period of 5 to 15 seconds, depending on the size of the fish. After the treatment the net along with the fish should be rinsed in clean fresh water.

Worms. Among the worm parasites of pond fishes, the trematodes of the genera Dactylogyrus and Gyrodactylus are the most important.

The adult Dactylogyrus measures 0.2 to 0.5 mm and attaches itself to the gills by means of rows of spines (14 in the outer and 8 smaller ones in the inner row) at the tail end of the body. It is also generally parasitic on the gills. The infected fish rapidly lose weight and due to the continued disturbance of the respiratory mechanism will ultimately die.

In many cases combined infections of Dactylogyrus and Gyrodactylus and Ciliate protozoans have been found.

Infection takes place mostly as a result of poor nutrition and unfavorable environmental conditions. The improvement of these conditions is an effective treatment. If noticed in the early stages of an epidemic, the infected fish should be removed from the pond and destroyed. Slight infections can, however, be treated by the application of a 1:100,000 solution of potasium permanganate or a 1:2500 solution of formalin for about half an hour.

Gyrodactylus is very similar to Dactylogyrus but is morphologically distinguishable by the absence of eyes and the presence of only a single row of 16 spines on the attachment organ as against the two rows found in Dactylogyrus. The parasite is viviparous. It has a definite preference for the skin of the hosts. The preventive and curative measures are the same as for Dactylogyrus.

CAPTURE AND MARKETING

The capture and marketing of the fish crop raised in a pond are as important as the cultural techniques. Capture operations may start a few months after stocking, to thin out the stock. Before using any fishing nets it is necessary to remove all weeds or other obstructions that may be lying in the pond.

Fishing Gear

Drag nets and cast nets made of cotton are the most common fishing gear used. A drag net is a rectangular piece of netting with a foot rope and a head rope. The head rope may be provided with floats and the foot rope with weight so as to keep the net fully stretched when dragged.

The length and breadth of the net are determined by the extent and depth of the area in which it has to be operated. The net is dragged from one end of the pond to the other and the catch is then hauled up.

Cast nets are conical in shape with lead weights at the periphery and may be stringed or stringless. In the stringed type, the hauling rope may have a radiating system of strings attached to the periphery. When the fully spread net is thrown over the fish the rim of the net sinks, thus trapping the fish below. When the net is hauled the rim is drawn together forming a bag or pouch in which the fish are caught. In the stringless type the rim forms the entry to a shallow bag.

Both cast nets and drag nets should be regularly treated with suitable preserving materials and dried in the shade. The best way of storing them is by hanging on beams or poles.

When a pond is fished to thin out the population, a drag net of a suitable mesh is preferred as it is easy to sort the catch in it than in a cast net. For large-scale fishing the drag net is used, but because several men are needed to handle it, the cast net is more economical for catching small quantities of fish. Small boats may be required to operate the nets in very large ponds.

Partial fishing can often be easily done by letting a good supply of fresh water flow into a pond from a nearby source. When a current of fresh water flows into a pond there is a tendency for the fish to swim towards it and collect near the inlet. Grey mullet and many other fishes have the habit of swimming against currents when many of them can be easily caught with cast nets. In some ponds a "fish race" is built for this purpose.

The most efficient means of capturing all the fish from a pond is to drain it completely. While draining, the outlet is covered with a suitable net or sieve to prevent any fish from escaping with the out-flowing water. There is generally a deep portion near the outlet where all the fish will collect when the pond is drained. If this portion is made into a regular catching tank and an open box with a small-meshed grill is fitted into it, all the fish can be easily collected.

Marketing

The demand for pond fish is to a large extent due to the fact that they can readily be had in a live state. The price that can be obtained for live fish is higher than for dead fresh fish. The cultivated fish being generally hardy and sometimes even capable of living out of water for appreciable periods, it is not very difficult to transport or maintain them in a living state. Fish that have accessory respiratory organs, such as the climbing perch, the murrels, the catfish and gourami can be transported or kept alive for quite long periods in any type of container with a little water to keep body and gills moist. These live fish often travel long distances in the holds of boats. Sometimes a separate enclosure is made in the pond with strong netting or bamboo gratings fixed in position by poles stuck into the pond bottom. The catches from the pond are immediately transferred to this enclosure and removed and sold when there is a demand. Or separate small subsidiary ponds can be dug near the main ponds for the same purpose.

Cages made of bamboo or wood are useful for keeping fish alive in a pond and also for transporting them through water. A live cage for the transport of fish should be streamlined to facilitate easy towing by a boat. This method is possible only when the market can be reached along an inland water route. For transport by road, wooden or metal tanks containing water are often used. Canvas tanks in motor vehicles are very suitable for carrying fish to market.

Over very long distances it may be necessary to aerate the water with a pump or from an oxygen cylinder.

The fish can be kept alive at the market in cement cisterns. If running water can be supplied they will live for several days. They should, however, be properly fed to maintain their weight and condition. Storing fish in clean water in this way will remove any muddy flavor they may have acquired in the pond. A concrete tank, 3 m by 2 m by 1 m will keep 100 to 300 kg of fish alive for several days if running water is provided.

For small quantities of fish, steel or wooden tubs can be used and a supply of flowing water can be arranged by placing a large bucket or drum with a hole at the bottom, at a higher level in such a way that there will be a steady flow of water from it into the tub. Excess water from the tub can be run out through an opening in the bottom. Where it is not possible to keep fish alive on the farm or in the market, the catches should be sold as soon as possible. If the market is far away, ice will have to be used. If there is a demand, the fish can be cured in salt and sun-dried.

FISH CULTURE IN LAKES, RESERVOIRS AND CANALS

Besides ponds, there are other natural and artificial waters such as lakes, reservoirs and irrigation canals which are suitable for fish culture, but culture methods in such waters are basically different from those in ponds where a fairly complete control of conditions is possible. In extensive waters fish are reared more as part of a general fishery improvement program than as pure fish culture.

A considerable amount of work has been carried out in the Indo-Pacific Region on the improvement of hill streams in certain areas for the culture of game fishes like trout, following the lines of western countries. But since these practices contribute relatively little to the production of fish for food it is not proposed to describe them here. On the other hand, the rational management of lakes, reservoirs and irrigation systems is of great significance in food production.

The improvement of lakes and reservoirs is a recent development in fish management and is still in its infancy, although several experiments undertaken have proved successful, especially in the United States of America. An integrated system of lake and reservoir improvement as applicable to conditions prevailing in the Indo-Pacific Region has yet to be evolved. Stocking of such waters with economic species of fish and fishing experiments in deep reservoirs have, however, been undertaken, although much work still remains to be done.

Hydrobiological Features of Lakes and Reservoirs

Several definitions have been offered for the term lake, but none of them is considered ideal. The description of a lake as a body of standing water occupying a basin and lacking continuity with the sea has found favor among limnologists. Reservoirs have many of the hydrobiological features of lakes, but differ in certain aspects in that they have been formed by submerging river basins and borderline land or by the construction of dams to collect water from an extensive catchment area. Studies on the limnology of lakes and reservoirs have been made and the book on limnology by Welch (1935) contains a fund of information on the subject. Much about the limnology of lakes and reservoirs in the Indo-Pacific Region was published in a series of supplements to the "Archiv für Hydrobiologie" (1930 to 1950). These publications contain the scientific results of the German Limnological Expedition to the Sunda Islands in 1939.

Lakes and reservoirs differ in size, depth and elevation. Seasonal fluctuations often occur in these waters as evidenced by the formation of increasing areas of exposed beach during the dry months and the submerging of marginal low land during rainy seasons. A wind-swept shore is a characteristic feature of many lakes and reservoirs. Except at rare times of complete calm, the waters of lakes and reservoirs are in constant motion of varying intensity, mainly due to wind. As a result of this the original shore line may be modified by shore cutting and shore building processes.

The most productive area of a lake or reservoir is the marginal shallow zone. An undue decrease in the water level, which would result in exposing considerable portions of this zone, may therefore restrict the productive area. Lake or reservoir bottoms, which in shallow waters are of significance in productivity, differ widely with age, history, etc. The main sources of bottom materials are: (1) bodies of plankton organisms which die and sink; (2) plant and animal remains from the littoral zone; (3) wind-blown materials, both organic and inorganic; (4) silt, clay and similar materials introduced by tributaries or washed in directly by run-off water from adjacent slopes; (5) marl, largely calcium carbonate, produced by plants and animals or

precipitated from the water by chemical processes; (6) remains of floating surface vegetation; (7) eroded materials from the shore zones. On the quantity and composition of these deposits, especially in the shallow regions, depends the fertility of the waters.

The influence on organic life in ponds, previously described, also applies to lake fish. Being more exposed to wind action and currents the turbidity may be more intense in lakes than in ponds.

Another important factor that influences the suitability of a lake or reservoir for fish life is temperature. In large lakes and reservoirs the thermal stratification is naturally more pronounced than in ponds, but observations so far conducted seem to show that a true thermocline seldom develops in these lakes. This enables continuous mixing of waters and a more rapid circulation of nutrient elements. Such waters are highly exposed to wind action and this is a factor that helps continuous mixing. The higher biological productivity observed in tropical lakes and reservoirs seems to be largely a result of this mixing. The horizontal currents caused by the wind and the returning currents formed by the excess water piled up on an exposed shore by an on-shore wind, returning underneath along the bottom, influence this mixing. The magnitude of mixing may, however, be dependent on the depth of the lake and may be either partial or complete.

The chemical conditions in a lake or reservoir also follow to a large extent the thermal pattern. The gaseous contents may become homogeneous due to the mixing. But in deep waters there is often stagnation because of incomplete lack of circulation. Observations in some of the reservoirs and lakes in India and Indonesia have shown the complete absence of oxygen in the deep waters during certain seasons and the formation of large quantities of gases like hydrogen sulphide and methane at the bottom due to organic decomposition.

Biota

Lakes and Reservoirs

The biota of lakes and reservoirs are those adapted to life in lentic environments. In reservoirs, formed by the construction of dams across rivers, the biota will be predominantly riverine, except that forms unable to live in lentic habitats will disappear. The planktonic flora and fauna is to a large extent similar to that of ponds, previously described. But the circulation of water as mentioned above will influence their distribution considerably. The greater depth of lakes and reservoirs may also cause a zonation of plankton.

The macrovegetation is of special significance in the suitability of lakes and reservoirs for fish life. In large bodies of water, like lakes and reservoirs, adequate growths of weeds are necessary to afford protection to fish life, as control of predators may not be possible in such environments. Vegetation provides refuge to young and adult fish, and weed beds form the main type of effective natural cover in lakes. Even the benthic vegetation such as "moss" is useful as shelter for the larvae of certain fishes. One of the main items of lake improvement in the United States is the provision of weed beds or brush shelters for the fish.

According to Hubbs and Eschmeyer (1935), major factors that affect weed growths are (1) latitude, (2) altitude, (3) topography of the bottom, (4) fluctuations in water level, (5) exposure to waves (6) turbidity, (7) fertility of water, (8) presence of harmful chemicals in the water, (9) suitability of bottom material, and (10) abundance of algae. The meteorological conditions of a locality, such as the extent of daylight, greatly affect the growth of plants and the type of vegetation that can grow in it.

As regards the region, it is fairly well known that in relatively pure and cool waters of higher altitudes plant growths are more sparse than in the warmer fertile waters of the plains. In some lakes and in most reservoirs the water level fluctuates markedly especially when the water is used for irrigation purposes. This often results in the exposure of fertile shallow marginal areas and may affect weed growth considerably. Exposure to waves adversely affects the growth of marginal weeds. As already mentioned, turbidity caused by agitation of a soft bottom, the erosion of shores, drainage or plankton growth is a great limiting factor in the growth of vegetation. It has been found that by the introduction of vegetation into a lake the turbidity of the water can be greatly reduced. The colloidal clay particles suspended in the water are negatively charged with electricity. Decaying plant material or other organic matter, such as sludge or manure, provide the positive ions which bring about a neutralization of the negative charge on the colloidal soil particles, allowing rapid precipitation. Plant growth on shoals may be greatly diminished by shade, and the shading out of submerged vegetation by broad-leaved surface vegetation has already been referred to.

The nutrient contents of the water is another very important factor affecting the growth of plants. In new reservoirs and lakes the quantity of nutrient substances in the water will often be limited and soft waters are often deficient in the nutrients needed for satisfactory plant growth. Admixture with pollutants, acidity or extensive lime encrustations also limit their growth. The nature of the bottom may influence the growth of plants in lakes and reservoirs by supplying the necessary nutritive material for their growth and by the provision of suitable substrata for the seeds to germinate. The acidity or alkalinity of the bottom also has considerable influence, as well as the shifting of sand or gravel on the bottom due to wave action. Too hard bottoms are unsatisfactory as they do not allow plants to root. The fact that planktonic, attached and filamentous algae are known to compete with higher plants in water areas indicates that the presence of algal blooms in lakes and reservoirs may inhibit the development of suitable weed beds. In lakes with such profuse growths of algae it is necessary to control their growth to establish a healthy macrovegetation.

As in ponds, uncontrolled growths of macrovegetation are inimical to normal life in lakes and reservoirs. While it is not too easy to eradicate weeds from ponds, it is extremely difficult in large lakes and reservoirs. The application of chemical weed killers is expensive and their effectiveness in deep bodies of water rather doubtful. The most practical method would appear to be mechanical removal of excess weeds, supplemented by weed killers wherever feasible.

The animal life in a lake or reservoir is dependent to a large extent on its depth. It is well known that organic life is more plentiful in shallow waters and therefore the fish productivity of such waters will be higher. One point of special significance in the culture of fish in lakes and reservoirs is that, unlike in ponds, it is not possible to restrict the fish fauna to cultivated fishes alone. The fish stocked in these waters have to live in association with the autochthonous predaceous and non-predaceous fishes. In most reservoirs these fishes account for a good part of the fishery. However, it is possible to control the population of predators to some extent by regular selective fishing. For the proper management of a lake or reservoir it is therefore essential to have an adequate knowledge of the habits of the autochthonous fish fauna. Since their migratory patterns may differ widely with topographical and hydrological conditions and the nature of fish fauna, specific investigations should be conducted for each lake or reservoir separately. These studies should give a clear knowledge of the breeding and feeding grounds of the fish populations and it will then be possible to undertake improvement programs, if found necessary.

Crocodiles and turtles often take a heavy toll of the fish in such waters. In some of the reservoirs of India it has been found possible to destroy crocodiles in appreciable numbers by poisoned bait.

Swamps and Irrigation Canals

Swamps, the last stage in the evolution of land from lakes, are extensive shallow water areas often overgrown with rank vegetation. The hydrological conditions in shallow swamps are very similar to those of shallow ponds. The vegetation may be of the mangrove type and there may be very thick deposits of organic matter at the bottom. Others have the same limnological features as rice fields. Very shallow swamps can be converted into fish ponds which can be managed in the manner described in previous chapters. Swamps with large areas of deep water cannot be so converted but can be managed in the same way as lakes. Saline swamps are suited for conversion into brackishwater ponds where euryhaline fishes can be profitably cultivated. A modern method of reclaiming a swamp is to drain it into a selected deep portion within it, known as the sump, which can be deepened and provided with an embankment if necessary. Fish can be cultured in the sump and the drained area will become available for agricultural purposes.

Swamps in the Indo-Pacific Region usually have a fish fauna consisting of hardy air-breathing species, and predaceous fishes may be found in large numbers. But it will be easier to capture them in swamps than in lakes, on account of the shallowness of the water. As a result of thick growths of surface and submerged macrovegetation, and the consequent obstruction of sunlight, there is generally less growth of planktonic organisms in swamps. Control of macrovegetion is therefore a very important aspect of their reclamation for fish culture. The substratum being generally rich in organic nutrients, good growths of plankton should develop when the excess macrovegetation is removed.

Irrigation canals carry water from reservoirs or rivers to irrigate agricultural land. While the biological properties of the water will therefore depend to a large extent upon the properties of the feeder supplies, the hydrological features will be similar to those of small rivers. Since the supplies of water fed into the irrigation canals are determined by the requirements of agricultural crops there is a likelihood of marked variations in the water level.

The flowing water in irrigation and navigation canals contains considerable quantities of oxygen and can therefore sustain large populations of fish if adequate fodder can be supplied, as in the flowing water ponds of Japan. It has been found possible in suitable localities to partition off sections of canals with strong bamboo or metal fencing through which the water can flow freely but which prevent the escape of the fish. Where this is not possible, an entire canal system can be managed as a single unit in which fish which do not migrate to long distances can be cultured. The chances of not being able to capture the fish stocked in the area would thus be minimized.

A system which is gaining popularity in some of the countries of the region is the rearing of fish (chiefly catfish) in bamboo pens in rivers or canals. The culture of the common carp in such pens has been applied with remarkable success in Indonesia and Thailand. The size of the pens varies from that of a large basket to as much as 6 meters square or more. They can, of course, be constructed in any shape but a streamlined form is preferable in a canal with flowing water. In the case of common carp, which feed at the bottom, the variety of benthic fauna, especially chironomids brought by the slow current of water and which accumulate below the pens placed on the canal or river bottom, serve as food to the fish and accelerate growth. By this method it will be possible to utilize the productive capacity of canals and other natural water areas without the risk of losing the fish stock during floods.

Stocking and Management

Stocking Lakes, Reservoirs and Swamps

As already pointed out, the fish fauna of a lake or reservoir under cultivation would not consist entirely of introduced species only. In fact, in most such waters a sizeable portion of the fauna consists of indigenous fish. Among these there is likely to be a large number of predators. In small lakes and swamps it may be possible to use fish poisons, such as rotenone, to kill all fish before stocking operations are undertaken, in which case there will not be any appreciable number of competing or predatory species left. Well controlled culture operations similar to those employed in large ponds would then be possible in such waters. But in large lakes it may not be practicable to use fish poisons effectively, and intensive selective fishing may be the only possible means of controlling the predators or weed fish.

It is often possible in reservoirs to check the predators effectively if proper measures are adopted well before the reservoirs are filled. Except in those built on the lower reaches of rivers, the head waters of most reservoirs consist of small streams which shrink into a chain of shallow pools during the hot dry season. It will be very easy to catch all the fish from these pools and connecting water areas with nets or kill them all with poisons or dynamite. If this is done before the reservoir is filled the risk of predatory or weed fish entering will be greatly diminished, provided proper precautions are taken against their migration into it from below the dam or connected water areas.

For stocking lakes, reservoirs, swamps and irrigation canals, any of the cultivated freshwater fishes listed can be employed, depending on their availability, local demand and profitability. In water containing large quantities of submerged plants it will, however, be advisable to stock macrovegetation-feeding fishes like Puntius javanicus, Punten carp or gourami which have proved to be of great use in controlling vegetation.

Ordinarily it will be necessary to rear the fish to a size of about 15 cm before stocking them in such waters. For this purpose there will be a need for nursery and rearing ponds in the vicinity. In the case of reservoirs, the construction of such ponds should not be difficult, as several borrow pits and similar excavations would have been dug to build the dam and auxiliary structures. Water may be readily available from the reservoir itself. For lakes and swamps, suitable natural ponds may have to be found or new ponds have to be made for the purpose. Fingerlings raised in small rice fields can be used for stocking irrigation canals.

Besides the young fish thus obtained, there are other means of increasing the stock in a reservoir. When the sluice gates of a dam are opened large numbers of fish gather below the dam and swim against the current. If a suitable fish-pass is provided they will enter the reservoir but precautions should be taken against the entrance of predators or undesirable species. Even when a fish-pass does not exist, it may be possible to lead a number of fish into the reservoir in the early stages of the dam construction by providing inexpensive devices which break the force of the current when the sluice gates are opened.

In our present state of knowledge it is rather difficult to set out any specific stocking rates for lakes, swamps, reservoirs and irrigation canals. The density of indigenous fish population and the fodder resources of the water have to be considered in working out a suitable stocking rate. The well known methods of population estimation and surveys of biota should be used for the purpose.

In most cases it is not necessary to continue stocking after a few years as the species establish themselves and multiply. Even fishes like catla, rohu and mrigal which do not breed in ordinary confined waters will spawn in suitable breeding grounds on the marginal zones of reservoirs. Improvements, such as providing adequate shallow marginal areas near streams flowing into the reservoirs would appear to facilitate their breeding.

Other helpful measures are shelters and fertilizing with suitable manures. As already pointed out, very little work has been done in this region to justify any firm recommendations in this respect. The results of experiments conducted in Michigan lakes on these lines were described by Hubbs and Eschmeyer (1935) and could form the basis for experimental work in the region. Growing weed beds and setting up brush shelters could be tried in areas where sufficient shelter does not exist. Fertilizing extensive reservoirs, lakes and similar waters would require large quantities of manure and it is doubtful whether any of the countries in the region have any fertilizers to spare for fish culture, especially when their efficiency and profitability have not been established conclusively. However, it is worthwhile conducting experiments to examine its feasibility.

In multipurpose reservoirs there is the risk of fish being drawn into turbines, power intakes, irrigation canals and other erections. Fish screens of different types are used in western countries and also in some Japanese dams. The defect of stationary mechanical screens is that they may get clogged with solid matter unless steps are taken to keep them clean. The removable rotating screen protected by trash racks is considered to be the best of its kind.

Stocking in Pens

Rearing pens of bamboo should have no sharp edges to injure the fish. Generally only fingerlings or more grown-up fish are used; for example, in Cambodia, young Pangasius of about 80 to 150 g are stocked. A floating pen 7 to 10 m long and 2.5 to 4.5 m wide and 1.5 to 2 m deep, will rear seven to eight thousand Pangasius. Hardy species like catfishes, murrels, climbing perch and common carp are suitable for this type of culture. The pens may float or be fully submerged, resting on the bottom. Besides supplies of natural food that flow into the pens, the fish can also be fed with suitable artificial food which is given twice a day through a trap door in the pen. Feeding should be so regulated that all the food is eaten before being washed away. Floating pens should be protected against the sun and it is the usual practice to cover a part of the pen with aquatic plants.

Fishing and Marketing

One of the difficulties of fish culture in deep lakes and reservoirs is the paucity of suitable commercial fishing methods, particularly if the bottom has not been cleared of obstructions. Drag nets cannot be operated in such waters. Cast nets can be used from the banks or from small boats, but they are not suitable for the deeper areas, and in shallow lakes with level bottoms, seine nets may be effective. One type, the Rangoon net, is made of fine yarn, rectangular in shape, the length and breadth varying to a certain extent with the locality. In very large areas several pieces of netting can be joined together to form a long net. The head rope has a number of floats, the thin foot rope has none. Nets made from nylon are more efficient than cotton.

In use, the net is vertical. One end can be tied to a wooden post fixed on the bank and the farther end kept in position by a float, and the net is then hauled from the bank. If operated away from the shore, the net is kept upright with two large floats, one each end, paid out and hauled from small boats. Very cheap but efficient homemade coracles are used.

The net is generally set in the evening and the catches removed the next morning. The size of the fish caught, of course, depends on the mesh. Large-meshed nets (6.4 cm from knot to knot) to prevent the taking of undersized fish, are common in India. The Rangoon net is for surface fish only. A similar type of net known as Udu valai in Madras can be used for bottom fish. This is weighted at the bottom, but it can be used only for fishing the shallower marginal areas. Longlines are very useful for the deeper waters. Another method of fishing, with electricity, might solve the problem of fishing in deep waters.

Large sheets of water may become very rough during certain seasons and the transport of catches to the landing place in fresh condition may become difficult. Small power vessels to tow the fishing boats will help in such circumstances.

The methods of preservation and transport to be employed depend largely on the size of catches. When the source is near a town the catches can be transported and sold fresh or preserved in ice. Fish can be kept alive for short periods in cages or wells of the type previously described. When catches are large it may be necessary to set up small refrigerator and cold storage plants in the vicinity and an organization for marketing. In times of glut a portion of the catch can be preserved by salting or brine-curing, followed by drying. If there is a good demand for fish so treated, it may often be more economical to preserve the catches in this manner. The trash fish caught, if available in sufficient quantities, can be converted into fish meal or manure. In some countries conversion of freshwater fish into fish pastes or sauces is a highly profitable industry.

The economics of fish culture in lakes, reservoirs and the like should be examined, bearing in mind the fact that fish culture is only one of the various means of productive utilization which can be carried out without detriment to other projects. The outlay necessary for fish culture or fish management is relatively small, and will be more so after the first few years, if the fishes stocked in such waters have established themselves and begun to breed. Fishery development in them provides a living to hundreds of fishermen and local inhabitants, besides making available cheap and nutritious food to the people living in the inland agricultural areas or in industrial townships connected with multi-purpose power projects. However, as has already been pointed out, these activities cannot easily be integrated with a rural economy as ordinary pond culture, and have to be organized as state or cooperative endeavors.

Sufficient data are not available to lay down any standards of expected productivity in lakes and reservoirs. It is now fairly well known that the per hectare production of a water area such as a pond or lake decreases sharply as its area increases beyond a few hectares, and that it is the shallow areas that contribute in a large measure to its productivity. Tropical waters are known to give higher yields, and at least double the production obtained in Europe or North America can be expected in the waters of the region. Experience in India has actually shown that a high production can be attained under favorable conditions, as has been demonstrated in the Mettur Reservoir. The Tempe Lakes in Indonesia were stocked with plankton and plant-feeding fish in 1937, and they are now producing 250 to 2,500 kg of fish per hectare per annum. The area which did not produce any fish for export before 1937 has now a marketable surplus of several thousands of tons of dried fish per year.

FISH CULTURE IN PADDY FIELDS

Most of the countries in the Indo-Pacific Region have an agrarian economy and the majority of the population is engaged in agriculture. Rice being the staple food of the people, paddy fields occupy a great share of the arable land. As is well known, it is necessary to keep a certain depth of water in the fields for the cultivation of most strains of paddy, and since many of them are left fallow for varying periods of time after the crop is harvested, such fields offer conditions well suited for the cultivation of fish. When well fertilized and inundated for paddy growing, rich biota develop in the water and these can be utilized for the production of fish. In countries like India, Vietnam, Malaya and Indonesia the farmers have always got crops of fish or prawns from flooded paddy fields which naturally get stocked with fry when being filled with irrigation water. The next stage in evolution was the artificial stocking of the fields and giving proper care and protection to the fish to obtain increased yields. Fisheries agencies in many of the countries have taken an active interest in extending and improving the techniques, and much research has been conducted on this subject in countries like Japan and Indonesia.

Advantages

The culture of fish in paddy fields can be of great significance in the economy of rural areas in this region. It can provide a supply of cheap and wholesome protein food, besides affording an additional income, and the culture of fish in fields flooded after the paddy harvest might serve as an off-season occupation for the farmers. Experience so far gained indicates that in most cases culture of fish along with paddy is beneficial to the latter. The fish feed on many of the noxious insects or their larval stages and thus indirectly contribute to a better production. In China it has been possible to control to a large extent the spread of a serious insect pest, namely the stem borer. The number of rats in paddy fields can also be checked; the greater depth of water maintained in the fields used for fish culture prevents rats from digging holes in the bunds and floods the holes that have already been made.

Another beneficial factor is the increased paddy tillering caused by the movements of the fish, which results in higher yields of paddy. The excreta of fish and the remains of food, if they are artificially fed, also serve as additional fertilizers in the fields. When a strongly herbivorous fish like tilapia is cultured, the growth of weeds is reduced, as it feeds on them and therefore the labor involved in weeding is reduced. Further, the farmer naturally bestows greater care on the field when he grows a double crop and this considerably increases the chances of a good yield of paddy.

Even though fish culture in paddy fields has great possibilities in the region, it has to be recognized that not all types of fields are suitable for the purpose; adequate irrigation and drainage facilities are essential for success. In areas where there is heavy seepage of water, or where drought occurs frequently, fish culture is extremely difficult. Similarly, facilities for the construction of suitable dams and channels are essential, as all fish may be lost in floods.

All strains of paddy are not suitable for raising such a double crop. It may be necessary to maintain a greater depth of water in the fields for fish culture and only strains that can tolerate deep water and the low temperature prevailing in such waters will thrive. If the water temperature drops below the optimum level, growth and production of paddy may be affected. Paddy varieties with strong roots are necessary for combined cultivation with common carp, as otherwise the fish may uproot the plants and thus damage the main crop.

Types of Fish Culture

Fish culture in paddy fields can be divided into three types, namely:

(a) as a secondary crop after paddy;
(b) along with the paddy during the period of cultivation;
(c) a continuous cultivation, transferring the fish to specially prepared ditches or channels during the paddy harvest or at other times when the fields are drained.

Where there are sufficient irrigation facilities and a continuous supply of water can be maintained in the field, fish can be raised as the only secondary crop, as in certain areas of West Java. The fish may be species introduced from elsewhere or wild fish brought in with the water that is let into the fields. The interval between harvesting and the next planting may be partly used for drying the fields and partly for short-term fish culture. Continuous inundation is not desirable for some soils since they may then become less suitable for cultivating agricultural crops. In such cases an additional secondary crop like groundnut can be raised after draining the fields.

In rearing fish with growing paddy, the duration of culture varies widely. It is often necessary to drain paddy fields for weeding once or twice during a season. Later, the fields have again to be dried for certain periods, to promote proper flowering and ripening of the crop. Fish culture in these fields must therefore be confined to the intervals between successive inundations and drainings. In areas where there is a demand for small fish, quick-growing species can be raised to a marketable size during these intervals, which may range from about 24 to 50 days. When facilities are available for temporarily storing the fish when the field is drained, it is possible to grow them for the whole paddy cultivation period which may be from three to six months, or, as practised by the Japanese fish farmers, from two to three years by transferring the fish to suitable ponds.

The Chinese fish culturists in Taiwan have also evolved a system of continuous fish culture in paddy fields. The fields have channels into which the fish are gathered when the fields are dry.

Water and Soil Conditions

The depth of water and the fertility of the soil and water are the most important factors that determine the production of fish in paddy fields. Wet rice fields in general are suitable, but the most successful fish culture is achieved in areas where controlled irrigation is practised, that is, where the fields are drained and inundated at will. When the fields depend on the rains for water, unfavorable conditions may occur in periods of drought, but when there is a good water supply, the depth of water can be regulated to suit the height of the paddy plants and to maintain optimum temperature for the plants. Where the paddy strains are sufficiently resistant, a depth of about 30 cm of water can be maintained.

If fish are cultured after harvesting the paddy, larger quantities of water can be let in.

The shallow water that has to be maintained in planted fields calls for precautions to prevent fish mortality. The water temperature may rise unduly and unless there are deeper pools or channels in the fields, where the fish can take refuge, the heat may kill them. High temperatures may result in a low oxygen content or, when the field is flooded without removing the paddy stubble, it decays in the water and may use up a large portion of the dissolved oxygen.

However, because of the shallow water and the large surface exposed, re-aeration takes place fairly quickly. In areas such as Malaya, where re-aeration is not rapid, only fishes with accessory respiratory organs are able to thrive.

Most paddy fields are flooded with fresh water, some strains of paddy are resistant to brackish water and in the fields where they are grown, euryhaline fishes like mullets and tilapia and brackishwater prawns can be raised successfully.

Whatever cultural measures are taken, the yield of paddy from a field is largely dependent on the fertility of the soil, and it usually follows that fields that give good yields of paddy also produce good crops of fish. Farmers generally fertilize the fields before sowing or planting paddy and when the field is inundated, some of the nutrients dissolve in the water and give rise to the growth of plankton.

The nitrogen content of the soil in a paddy field used for carp culture, and fertilized in the usual way, is less at the beginning of carp rearing than it is at the end of the period. It appears that in the early stages of cultivation there is a rapid consumption of nitrogen by the phytoplankton and as the paddy crop grows, the nitrogen content of the soil increases due to the deposition of fish excreta. When the fish are artificially fed the soil has a still higher nitrogen content. It has been found experimentally that this variation in nitrogen content does not adversely affect paddy growth.

Besides the nutrient content, the texture of the soil is also of importance in raising fish. In very porous soils it is very difficult to maintain the required depth of water, and the construction of impervious banks is also difficult in such soils.

Biota

The planktonic biota in a paddy field are almost similar to those of shallow ponds. It has been observed in Japan that the ratio of zooplankton to phytoplankton in paddy fields utilized for carp culture is less in the middle and later periods of the rearing than in ordinary fields. This is believed to be caused by the stirring of the water by the carp when searching for food.

Filamentous algae and weeds also grow in paddy fields and some of this vegetation is used by the fish as food and is kept under control by them.

Paddy fields often harbor various insects, some of which are injurious to the paddy. Mosquitoes may find the conditions suitable for breeding and in some localities mosquito larvae occur in large numbers. Fish, when cultured with paddy, feed on mosquito larvae and also on the adult insects.

The autochthonous fish fauna in fields are mostly weed fishes or those with accessory respiratory organs, such as murrels and catfishes, but being predacious, it is not desirable to have them present if intensive fish culture is practised. When the fields are drained, fish like the murrels bury themselves in the mud and survive until they are again inundated. Rats usually find suitable conditions to live in the bunds of paddy fields but, as already pointed out, fish culture can considerably reduce this menace.

Fish-eating birds especially night herons may take a heavy toll of the fish stocks. They, as well as otters, weasels, and other predators, can be kept in check with snares, traps, poison and other measures.

Preparation of Paddy Fields

A paddy field to be suitable for fish culture should have an adequate depth of water, and to retain this strong bunds are essential. If the bund is pervious, there will rarely be sufficient water in the fields for the fish to thrive. So, the construction of proper bunds is of great importance.

It is comparatively easy to make new bunds watertight. Old bunds should be ploughed and levelled, then the ground where the new bunds are to be built should be slightly dug up to a width of about 50 cm. The shallow trench, so framed, should be filled with fresh, moist earth, not too hard or too soft and wet, and free of grass, straw or weeds, well consolidated. More and more earth is then heaped over this foundation and rammed until the bund is about 35 cm above the level of the field. Such a bund when it dries will have an approximate height of about 25 cm. A height of about 60 cm is recommended for fields in which tilapia are cultured.

If an old bund has merely to be improved, the lower portion of it on the field side should be removed at an angle and replaced with fresh well-rammed earth. The ground below the bund should be treated in the same way.

Where the necessary preparations cannot be made before the paddy planting, a narrow channel can be dug on the inner side of the existing bund. The earth so obtained should be piled up to form another bund. A system of such channels is very beneficial for fish and essential for a program of continuous culture. The dimensions of the channels will depend on the size of the fish to be reared and whether they are intended only as temporary refuges or are to be used for a prolonged period.

It may be advantageous to erect a low bund along the inner side of the channel (opposite to the main bunds) if the field is to be used for continuous fish culture. When the field contains tender seedlings it is not advisable to allow the fish to graze in them because the seedlings may get damaged. Such low bunds prevent the entry of fish into the main part of the field. Later, when the plants have become strong enough, the bunds can be cut to let the fish spread all over the field. When there are cross channels in the fields these low bunds should be constructed on both sides of the channels. It will also be advantageous to dig a small pond connected to the channels. The channels and pond will give shelter to the fish from the sun's heat and from enemies like fish-eating birds. When draining the field, the fish can be gathered in the channels and ponds, which makes it easier to collect them from the fields.

The extent and number of channels are dependent on the size of the field. Channels can be dug all round in the middle only, or crosswise. In a narrow rectangular field, two or more channels may be dug across it with a single one down the middle. For a pond less than 0.5 hectare a channel around half of the field or along two sides of a square field is sufficient. The usual width of channel is about 50 cm and the depth about 30 cm. Ponds 1 m by 1 m in size can be dug at the points where the channels meet. A depth of 60 to 90 cm and a width of 1.2 to 1.8 m is recommended for rearing tilapia to an average weight of about 70 g.

The best time to excavate the channel is just after harvesting the paddy, but if necessary an all-round channel can be dug at weeding time. Suitable water inlet and outlet arrangements are needed with adequate control devices and screens. A spillway should also be installed at a suitable height, to deal with floodwater during heavy rains.

If fish are to be reared after the rice crop has been harvested, the field should be inundated without removing the stubble. The depth of water will depend on the size of fry or fish introduced.

The decaying vegetation will encourage a good growth of plankton, and some of the stubble may also be consumed directly as food by the fish. In sub-tropical regions an important factor in regulating the depth of water is the degree of flooding that the particular strain of paddy can stand. For tilapia a depth of 7.5 cm is sufficient. Javanese farmers maintain a depth ranging from 4 cm to 20 cm, depending on the size of the fish reared; in India, a depth of 10 to 60 cm is common. It is the general practice to let in fresh supplies of water at intervals of about 10 days to meet the increasing requirements for space, oxygen and nutrients by the growing fish. However, it is generally believed that constant fluctuations in water level are not conducive to a good growth of fish.

Before farmers plant paddy they ordinarily fertilize the fields with chemical or organic manures. Almost all the manures used for paddy are beneficial for fish culture, except a few chemical fertilizers, such as calcium cyanamide, which are poisonous. Organic manures are preferable for common carp because they encourage the growth of phyllopods, such as Daphnia or Moina, which are important items of food. Fish also feed directly on organic manure.

The quantity of manure applied in a paddy field should be increased by 50 to 100 per cent when it is utilized for fish culture. Japanese farmers spread organic composts over the fields that are to be used for common carp at the rate of 1,200 kg per 1,000 m^2 in the early half of April, if it is to yield one crop only in a year, but for two crops, the field is again manured after harvesting. There is no need to manure the channels because part of the manure applied to the field finds its way into them. Experimental work conducted in Japan has shown that the production of natural food for the common carp in paddy fields can be increased by the application of clover or other green fodder extracts.

Stocking

Although most of the cultivated fishes can be cultured in paddy fields, the species most suited are those that can

(1) thrive in very shallow waters;
(2) withstand fairly high turbidity of waters;
(3) tolerate relatively high temperatures and low oxygen content;
(4) grow to a marketable size in a few months.

Very active species and species that can travel over land are not well suited for cultivation in paddy fields, from where they may be able to escape easily. Common carp satisfies all the requirements and is therefore most widely used for the purpose. In Indonesia, an association of common carp, tilapia and tawes (Puntius javanicus) is now grown in paddy fields with success. Tilapia has proved a success in Taiwan and it is being tried with encouraging results in Thailand. In Malaya, where the paddy fields provide a good crop of fish, selective stocking has not been attempted. The fry of sepat siam (Trichogaster) and other fishes gain access to the fields with the water and they grow with the paddy. Before harvesting the water is gradually drained from the field. While many fish are collected in drainage ponds situated in the lower parts of the field, some always find their way into drains and irrigation channels where they breed and produce fry for stocking the fields during the next season. This method is also used to stock paddy fields with young prawns in Travancore-Cochin. The mainstay in Malaya is the sepat siam, but other species such as murrels and catfish (Clarias) also grow in the fields.

The stocking rate largely depends on the productivity of the water, the duration of culture and the size of the fish introduced. The Japanese farmers raise either one-year-old or two-year-old carps in paddy fields. For yearlings, the fields are stocked in spring with fry 5 to 7.5 cm in size.

By the fall, in a period of about 4 to 5 months, they grow to 15 to 18 cm in length and 85 to 115 g in weight. The general practice is to stock at the rate of 200 per ha or 12,500 per ha when additional food is provided. When yearlings are used as stocking material for raising a crop of two-year-olds, 1,200 to 1,600 fish per ha are stocked when no artificial foods are provided, and 4,000 per ha when supplementary food is given. Yearling fish are often kept over in deeper ponds during the winter to serve as stocking material for the next paddy-growing season. Sometimes the farmers stock their fields with a mixture of fry or fingerlings with yearling carp. In the Tonkin area of Indo-China a stocking rate of 1,200 common carp fry per hectare gives satisfactory results.

The main feature of paddy field fish culture in Java is raising several crops of small fish for which there is a ready market locally. Simizu (1944) described the carp stocking schedules followed there, which are summarized in the following table:

Common Carp Stocking in Paddy Fields in Java

Size of fry		No. per hectare	Time of stocking	Duration of culture	Expected mortality %
(1a)	3 to 5 cm	30,000 to 40,000	Between 5th and 7th week after sowing paddy (i.e., between 1st and 2nd weeding)	21 days	60
(1b)	Continued culture of (1a) when fry are about 8 to 11 cm in length		A few days after 2nd weeding, i.e., after the 7th week after sowing	50 days (when rice plants flower)	-
(2)	3 to 5 cm	10,000 to 20,000	A few days after sowing	About 40 days	40-50
(3)	3 to 5 cm	4,000 to 6,000	A few days after sowing	40 days	70
(4)	5 cm	1,000 to 2,000	About 5 days after sowing	40 days	40
(5)	8 to 11 cm	1,000 to 2,000	After the second weeding (about the 7th week after sowing)	50 to 90 days	30-40

In some paddy fields only tilapia are stocked. The stocking rate is so adjusted as to grow them to a weight of 50 to 100 g. When an association of common carp, tilapia and tawes are cultured, 750 to 1,500 fingerlings per hectare are stocked.

In Taiwan, where the temperature may become low in winter, the farmers stock their fields when the water has risen to about 15°C and is not likely to drop again. Stocking is never done until 10 days after the seedlings are planted and then only fry are used. If fingerlings are to be introduced, the farmers wait about three weeks after transplantation. This is done to prevent the fish from damaging the paddy plants. The recommended density of stocking is 7,000 to 8,000 fry or 12 to 180 kg of fingerlings of tilapia per hectare.

The various precautions and procedures described for pond stocking should be followed to ensure the stock gets well acclimatized to the conditions in the paddy field.

Management

Where the water is shallow, great care should be taken to protect the fish from predatory birds. This is why better yields are often obtained in fields near the farmers' homesteads. Excessive growths of filamentous algae can entangle fry, so they should be removed.

In fertile fields, especially when well-manured, fish food organisms grow in sufficient quantities for at least a month. Subsequently, to maintain an abundance of food, fertilizers should be applied as top dressings. About 2,000 kg of compost or 3,500 kg of night soil per ha is used in Taiwan. If chemical fertilizers are used, the field should be drained, the fish being gathered in the channels, before applying them. After two or three days the field is flooded again. Experiments conducted in Japan show that the growth of the favorite food of common carp, namely Daphnia or Moina, is greatly enhanced by the addition of green grass to the manure. Organic manures are more effective than chemical fertilizers for these organisms. The insects living among the plants, many of them harmful to the paddy, are readily eaten by the fish.

All the artificial foods mentioned previously for pond culture will increase fish yields in paddy fields. Some Japanese farmers raise small crustaceans in specially prepared ponds for the purpose, and earthworms, grown on decayed leaves, are also suitable for carp.

Regular inspection of the bunds and the water supply arrangements is essential and, when necessary, repairs should be quickly undertaken. If the field channels get filled up with mud they should be cleaned.

When draining a field for harvesting or weeding, the water should be let out slowly so that the fish can find their way into the channels or a catching pool and not get stranded. The Japanese farmers plough a few shallow furrows in the field, leading from the inlet to the outlet, with a deeper, firm bottom pool about half way between the outlets. The fish are directed into the pool as the water level in the pool goes down and when the whole field has been drained the fish can be scooped out of the pool with small nets.

Economics

The main fact to be remembered is that fish culture is only a subsidiary activity and the cultural operations should be modified to suit the requirements of paddy production. The income from fish culture is an additional one, and it provides a cheap, acceptable and nutritious protein food, in fresh condition. Rice yields are often increased in the presence of fish, sometimes as much as 15 per cent. A slight reduction in paddy yields has been recorded in Taiwan, due mainly to having the fish channels in the field taking up 5 to 7 per cent of the area, but even then, the money value of the fish produced more than compensates for the loss of rice.

The actual yield of fish depends largely on the species stocked, the duration of culture, the fertility of the soil and water, and the food provided. The Javanese paddy fields of cultured carp produce 30 to 50 kg per ha in 40 to 60 days, or a wild crop of about 3 kg of fish per ha in a period of six months between two paddy crops. In Indo-China the yield is about 10 kg to 20 kg per ha over a period of two months. The Japanese farmers get an average production of 145 kg per ha per annum by rearing one-year-old carp without artificial feeding. With artificial feeding the yield can be increased to 2,250 kg per ha or more. In Malayan paddy fields the production ranges from 20 kg to 135 kg per ha per crop.

CULTURE OF FISH IN BRACKISH WATERS

General Considerations

The construction of brackishwater ponds is generally achieved as a step in the reclamation of low-lying coastal or estuarine swamps in the Indo-Pacific Region. Such areas, enclosed by embankments and irrigated with tidal water, gradually get raised by the deposition of silt. The saline content of the soil is washed out by rain and river water, which is allowed to flush the embanked areas and in due course the land becomes suitable for paddy cultivation. Thus, the ultimate aim is agricultural utilization and fish raising is intended to be done only during an interim period of varying duration. However, in recent years there is an increasing realization that sometimes it is technically feasible and profitable to manage such areas purely as fish culture establishments. So ponds are often constructed now for continued fish culture only.

The main factor that governs the selection of sites for the construction of brackishwater ponds is a good supply of tidal water.

Irrigation depends upon the characteristics of the tidal regime, the distance of the site from the sea and the accessibility of tidal water. Ponds situated near the sea or adjacent to the mouth of the estuaries receive salt water at every high tide. Farther up the estuary at distances depending upon the tidal regime of the river, there will be a constant supply of brackish water. Brackish water may be available only during the spring tides for ponds situated further inland. The availability of adequate quantities of salt or brackish water will also be governed by the level of the pond bed. When the pond bed is at a considerably higher level than the river bed, tidal water may not reach the farm at every high tide, and this may lead to a restricted supply of water.

Selection of Pond Site

As was previously stated, pond draining at regular intervals is an established practice in brackishwater fish culture in some of the countries of this region. An adequate tidal range in the feeder river is therefore an important criterion for the selection of sites for brackishwater ponds. Schuster (1951) considers a tidal range of 1.5 m essential for a brackishwater fish farm. Though a lesser tidal range may not be satisfactory for proper draining of the ponds, it will be possible to maintain brackishwater ponds in areas of lesser tidal ranges, if methods such as water pumping and manuring are adopted.

Requirements with regard to the type of soil and the situation of the site in relation to transport, nearness to markets, freedom from floods, etc., that are of importance in the selection of sites for the construction of freshwater fish ponds also hold good here. It will be advantageous to select sites where there is no need for excavation since this will keep down the cost of construction. In such areas a channel has to be dug all round the site to obtain the necessary earth for building the embankments. Clayey soil is the most suitable for pond bottoms and for the embankments. The type of local vegetation is of importance, especially from the point of view of labor and expenses for clearing the site. For instance, swamps overgrown with Nipa palms are more easily cleared than mangrove swamps as it is difficult to clear the mangrove stumps.

Layout of the Ponds

After the site for the fish farm has been selected, the layout of the farm has to be determined with due reference to the topography. Brackishwater farms are generally run as self-sufficient units with nursery or rearing and stocking ponds. Several layouts have been devised in various

centers and countries. The simplest type of pond is a sheet of water 0.4 to 2.4 ha in extent and 0.3 to 1.3 m in depth, fed through a wooden or bamboo sluice which controls the ingress and egress of water. When the ponds are made by excavation, large quantities of earth are piled up in the center of the ponds, so they may be irregular in shape.

In Java, the improved porong type of brackishwater pond is considered the most satisfactory. On an average, it is 7.5 ha in extent and consists of 3 to 10 irregularly shaped sections connected by secondary sluice gates, the whole being controlled by a main gate which is located in a deep portion having a channel in the middle. This portion is the lowest part of the farm and when it is drained the fish gather in this channel through branching leader channels dug in the pond bed. They also serve as refuges for the fish. Each porong type of farm has a fry pond about 90 to 900 m^2 and a rearing pond 900 to 4,500 m^2 in area. The embankments are 2.4 to 4 m high and 4 to 11 m broad at the base. Such ponds built on high land may have only a depth of 30 to 45 cm of water. During the east monsoon the central parts of the ponds become dry and only the channels and other deeper portions contain water. In very long ponds a deep channel is sometimes dug along one of the long sides. The sluice gates are so arranged that partial draining is possible.

Brackishwater ponds in Taiwan are known as wun, and one of their features is that they have a separate water supply channel feeding water into the several ponds through sluice gates. A wun may consist of anything between 3 and 30 sections and generally have nursery, rearing, stocking and wintering ponds. The supply channels are either situated along one side of the wun or between two rows of ponds. The width of these ranges from one to several meters. Water is taken into the supply channels from the sea through a sluice gate and similar gates regulate the flow into the ponds. Wuns situated on high ground have pumps on the embankment to supply water to the ponds. The rearing ponds are 100 to 200 square meters in area and less than 30 cm in depth. The rearing ponds have 90 to 120 cm of water and are rectangular in shape with a width of 3 to 6 m. The wintering ponds are deeper and windbreaks protect them from freezing.

Brackishwater fish farms in the Philippines are run either as self-sufficient units consisting of nursery and stocking ponds or as nursery farms only. A model fry farm consists of nursery ponds, known locally as pabiayan, catching ponds, known as kulungan, and a few transition or stunting ponds called impitan. There is also an elaborate channel system to supply water, known as sangka. Water is fed to the farm from a tidal canal or river through sluice gates. The area adjacent to the river or canal contains the deeper transition or stunting ponds and the rest of the land the nursery ponds. Water supply channels are arranged between two rows of nurseries. Every two nursery ponds have a common catching pond, which varies from 20 to 50 m in area. The nursery ponds have a number of small wooden gates and pipes to allow ingress and egress of water without allowing fry to escape. Water is usually taken into catching ponds from the supply channel through pipes. Water is let into nurseries from catching ponds through adjustable gates, but pipes are usually installed near them to prevent the escape of fry. The transition ponds are sometimes used as stocking ponds after the fry rearing is over. In certain types of fry farms, head ponds, which serve as water reservoirs, replace the water supply channels. These ponds can also be used for growing adult fish.

In a Philippine self-sufficient 10-hectare milkfish farm 1 per cent of the pond area is usually set apart for nurseries, 9 per cent for transition ponds, and 90 per cent for stocking ponds. The layout of ponds with slightly brackish water, in which grey mullet is cultured in association with carps in Hong Kong, is essentially the same as that of freshwater ponds.

Construction Methods

After the area has been properly surveyed, cleared and marked out, the first step is to build a strong embankment all round. The mode of construction of the embankment is essentially the same as described for freshwater ponds, but the height of the embankment is determined by the tidal height occurring in the area, generally about 30 cm above the maximum flood level. The survey will show whether or not the pond site has to be excavated. If it is not necessary, earth for the embankment is obtained by digging a marginal channel all round inside the pond site to the required depth. After the subsidiary embankments are made, further excavation, if necessary, is done. The slope of the pond bottom is so adjusted that it drains readily towards the outlet and, in large ponds, channels are dug to facilitate the draining. The sluice gates are constructed in the deepest portion of the farm. In West and Central Java, simple wooden or bamboo gates, provided with side walls and shutter boards fitted in a frame are used. More massive constructions 5 to 10 m long, 1.3 to 1.8 m wide and 2.7 to 3.7 deep are used in East Java where the tidal conditions require great strength. The sluice gate is made of heavy timber and the side walls are reinforced with wooden planks. There are five compartments in the sluice and of these four have wooden floors, whereas the fifth is kept filled with soil to the height of the average water level of the pond. Strong and well-fitting bamboo gratings, fixed on both sides of the gate, prevent the escape of fish.

In Indian brackishwater ponds, known as bheris, ordinary wooden sluice boxes with wooden shutters, that can easily be manipulated by hand, are used. In the Philippines more elaborate types are built for milkfish ponds. The main sluice is made of concrete or bricks, reinforced with concrete. To render the floor of the sluice strong and firm, bamboo or wood piles are driven into it. The floor is paved with stones and concrete and is often reinforced with steel bars placed over the piles. Three gates working in grooves are provided for each sluice. The central gate is made of strong wood and on both sides of it are split bamboo gates in wooden frames. The subsidiary gates for inter-connection between ponds are of the same design, but are made of wooden planks, nailed together. Wooden plank drains or cylindrical pipes are also used to connect ponds. The pipes are laid across the embankments with the ends projecting 0.5 m on both sides. These various types of drains are fitted with suitable shutters or plugs to control the water flow. Cement pipes are also used. When the pipes are in commission basket-like structures, known as galao, are fitted to the pipe.

It is a common practice in India to construct a V- or W-shaped bamboo grating behind the sluice gates to prevent the entry of undesirable fish or other animals. In Bengal rectangular bamboo traps with a funnel at one end, known as atols, are fixed in gaps left in the apex of the V or in the apices of the W. Bamboo spindles are arranged on both sides of the openings in such a way that fish or prawns can easily enter the trap but will not be able to escape from it. The atol is fixed facing the pond. When water is taken into the pond some fish swim against the current and get caught in the trap. This is a common method of collecting a few fish each day for the farmer's consumption.

Essential Conditions

Soil

The quality of the soil in a brackishwater fish pond is of even greater significance in productivity than in a freshwater pond. The quality of the underlying soil of an estuarine pond is to some extent dependent on the nature of the land drained by the river.

According to Schuster (1952) the most productive tambak soil in Java is generally obtained in the spill areas of rivers, the head waters of which are in the volcanic regions where the soil consists chiefly of ashes and incompletely weathered grit of volcanic rock. The clayey loam soil of deltaic areas in Bengal is also very fertile.

For the construction of ponds in coastal and estuarine flats the main factor to be considered is the water-holding capacity of the soil. Once the pond is made, silt is deposited quickly as a result of the stagnant conditions created. The organic matter brought in by the incoming tides disintegrates and adds to the fertility of the soil. The humus content of brackishwater ponds is generally high. Investigations conducted in Indonesia have revealed an average humus content of 4.1 per cent in the dry matter of tambak soil, and in inland ponds in West Bengal a humus content of 3 per cent has been recorded. Preliminary investigations in the Philippines have shown that algal production is best in ponds with soil having a high "solution loss" (determined by treating a sample of soil with hydrogen peroxide and washing), and high contents of clay, nitrogen and organic matter. The hydrophilic property of the mud has also been found to be of importance from the point of view of algal production, but this property is dependent on the clay and humus content and the tillage of the soil. Ponds receiving a satisfactory supply of tidal brackish water are generally rich in the various essential elements for algal growth. The nitrogen content of the soil is greatly enhanced by the nitrogen supplied by plants; Clostridium pasteurianum, Azobacter, Nostoc and Anabaena are common species which are supposed to fix atmospheric nitrogen in brackishwater ponds.

The quality of the soil in brackishwater ponds influences in a pronounced manner the type of biota that develop in them and, to some extent, the biota influence the property of the soil. For example, by prolonged inundation the pond mud absorbs large quantities of water and attains a jelly-like consistency. A soft hydrophilic and biologically active mud, containing large quantities of organic matter, develops a predominantly myxophycean flora in 1 to 50 cm depths of slightly lotic water. On the contrary, more or less solid soil, irrigated by water containing adequate quantities of nitrates and phosphates, Chlorophyceae grow more luxuriantly in 30 to 100 cm depths of stagnant water. The properties of the soil are effectively maintained by proper replenishment of nutrients absorbed from the mud by vegetation, by the dead and decaying algae and bacteria and through assimilation, fixation and absorption. In the absence of blue-green algae, certain soils lose their cohesive property and become semi-solid, and in others the fine particles of soil bind into sand-like granules which are with difficulty converted into mud again. On such bottoms the development of microflora is greatly restricted and microfauna takes its place.

The turbidity of brackish water shows a wide range of variability. Turbidity of estuarine water due to suspended silt is reduced in a short time in the ponds as a result of admixture with fresh water and consequent flocculation.

The water temperature of well-irrigated ponds does not fluctuate greatly. A variation between 24°C and 38.5°C has been observed in Indonesia. In shallow ponds in India a range of 14.4°C to 35.0°C has been recorded. Since in shallow ponds the water may become very warm during the summer months and cold during the winter, it is necessary to provide deep areas where the fish can take refuge at such times. In Taiwan, the fish are removed to deep wintering ponds protected by windbreaks which prevent the temperature falling to lethal limits.

Observations carried out so far in different countries show that the water in brackishwater ponds is always alkaline and that there is very little variation in the pH. The alkaline reserve is high enough to prevent wide fluctuations in pH. Preliminary experiments indicate that the pH of the water is of great significance in the growth of myxophycean algae, but further work is required to establish the optimum requirements in this respect.

The oxygen content of water in brackishwater ponds is dependent on temperature and salinity. Observations show that oxygen depletion is of very rare occurrence in these ponds. Any deficiency in oxygen on very hot days is made up by the oxygen produced by the carbon assimilation of algae. In fact, over-saturation of the water with oxygen thus produced has sometimes been noticed in tropical ponds.

Water

The two main sources of water supply are tidal water from the estuaries and rain water. As already mentioned, the availability of tidal water is dependent on the location of the ponds with reference to the tidal regime of the estuary. This, therefore, determines to some extent the depth of water in a pond. But even where there is a plentiful supply, the depth of water in a pond has necessarily to be controlled. In shallow ponds myxophycean algae grow in profusion, whereas in deep ponds Chlorophyceae predominate. In view of this, fish culturists adjust the water supply in such a way as to maintain the optimum level in the ponds.

The salinity tolerance of fish varies greatly. But it has been experimentally found that cultivated brackishwater fish can be acclimatized to fresh water by a gradual diminution of the salinity. Mullets and milkfish have been found resistant even to direct transfer from saline to fresh water. A salinity higher than 30 to 35 ppm is lethal to the fry of Mugil tade.

Water salinity is a very important factor that affects fish production in ponds. There are seasonal and diurnal variations in the salinity of every pond. In ponds receiving daily supplies of tidal water, the salinity fluctuates almost daily. During the rainy months feeding with tidal water might increase the salinity, whereas during other seasons the salinity is generally decreased by it. Due to evaporation and seepage a certain amount of loss of water occurs in every pond and this increases the salt content. The process of evaporation will be more rapid during the dry months and the salt concentration will therefore be greater during this period. Portions of the bed often get dried up and small pools and puddles are formed in shallow ponds. Deposits of crystalline salt are visible on the pond bed at this time and the salinity of the water in the pools is very high. But in the rainy season large quantities of fresh water are brought into the ponds by rain which dilutes the pond water and lowers its salinity. Ground water supplies also may lower the salinity. The seasonal and diurnal changes in salinity mentioned above naturally exercise a selective action on the fish fauna and only euryhaline species are able to thrive.

Very little information exists on the other chemical constituents of water in brackishwater ponds. Schuster (1952) estimated that a tambak in Java with a surface of 1 ha receives the following quantities of nutrients in every filling to a depth of 40 cm with water of 30 ppm salinity:

Phosphate (PO_4)	9 - 14 g
Nitrate-nitrite (NO_3-NO_2)	8 -140 g
Ammonia (NH_3)	20 -200 g
Potassium (K)	1320 kg

This does not include the nutrients that would be introduced by the silt in an absorbed form nor the nitrogen brought in with the rain water.

Biota and Their Control

Flora

As pointed out in the previous chapters, the nature of flora in a brackishwater pond is of extreme importance in fish production. A main feature of the flora is the relative scarcity of phanerogamic plants. This is more so in ponds containing water of a fairly high salinity.

Algae predominate and several genera and species of Myxophyceae, Diatomeae and Chlorophyceae grow luxuriantly on the pond bed and may also be found in the pond water, and several types of bacteria grow on the bottom mud.

In view of the very shallow nature of ponds generally used for brackishwater fish culture, it is often difficult to make a clear distinction between planktonic and benthic organisms. Many benthic plants get detached from the bottom and float in the water, and several planktonic algae settle to the bottom. The hormogonia, shed by the algae, occur regularly. However, it is the benthic vegetation that is of greater significance in such ponds, as most of the cultivated brackishwater fishes subsist on it. The organisms generally found in brackishwater ponds have been described by Vaas and Sachlan (1953). A large majority of them grow on the pond bed and often cover the entire surface. Several animalcules and considerable quantities of decayed organic matter may be found among them. The milkfish culturists of the Philippines recognize two types of these plant complexes, namely, lab-lab, in which myxophycean algae predominate, and lumut, in which Chlorophyceae predominate.

Detailed studies of the environmental preferences and seasonal fluctuations of algae in brackishwater ponds have yet to be undertaken in the Indo-Pacific Region. Preliminary work in India has indicated the importance of trace elements in algal growth. Several observations have revealed that the growth of halophytic algae is profuse and at a maximum during the winter months. Large sheets of algal growths are often buoyed up to the surface. This happens especially when there are good growths of Phormidium in the complex. The mucuous sheaths of the filaments of this often cover up the entire growths of algae, including diatoms. Oxygen released by the carbon assimilation of the algae accumulates inside the sheaths and ultimately lifts up the whole layer. The period of time taken for the development of a new layer of Myxophyceae on good soil is only about three days, whereas Chlorophyceae, such as Chaetomorpha and Entermorpha, need from four to eight weeks to grow to such profusion. Studies made in the Philippines show that the maximum growth of lumut is attained between the second and third months of their cultivation.

During the rainy season, when there is an admixture of large quantities of fresh water, some predominantly freshwater species of algae also may grow in the ponds. But considered as a whole, algal growth is at a minimum during this period. Some of the species of algae are found to be very resistant to high concentrations of salt. In the case of Phormidium tenue it has been demonstrated that it can withstand salinities up to 100 parts per thousand (Pillai, 1954).

Among the higher plants occurring in brackishwater ponds are species of Ruppia and Najas. Ruppia grows best in pure brackish waters but can withstand a salinity of up to 50 to 60 parts per thousand. Najas is less resistant to high salinities and the maximum it can tolerate is about 30 parts per thousand. The decayed leaves of these plants are eaten by milkfish and mullet. The fish culturists of Java drain off all the fresh water that has accumulated in the ponds during the rainy season, and fill the ponds with sea water of high salinity. This kills the Najas and Ruppia which are readily eaten by the fish.

The flora of the embankments is mainly of the mangrove type and consists entirely of halophytic species. In Java, mangrove trees such as Avicennia spp. and Rhizophora spp. are planted on the embankments of tambaks. The leaves of these trees are used as green manure for the ponds, the stem and branches as fire wood, and from the bark a marketable tanning material is prepared. The roots of the mangroves help to bind the soil and prevent erosion. Generally the mangroves are not allowed to grow for more than five years after which period they are cut down. By the third year, new seedlings are planted on the embankments.

Several other mangroves such as Sonneratia, Bruguiera, Xylocarpus, Lumnitzera, Aegiceras and Cerias also grow on the embankments, besides different genera and species of grasses. Suaeda, especially Suaeda maritima (family Chaenopodiaceae) is a characteristic plant of these areas and is used as a vegetable by many.

Overgrowth of vegetation in such a manner as to affect the growth of fish is a rare occurrence in well-irrigated brackishwater ponds. But weeds often occur in ponds situated inland since they receive large quantities of fresh water. The weeds have to be regularly removed to keep the ponds in a healthy condition. The need for selective growing of Myxophyceae or Chlorophyceae according to the size of fish in the ponds has already been referred to but, besides this, there is generally no need for any weed control in ponds. The areas occupied by extensive brackishwater ponds are devoid of sufficient shade and there is scope for planting tamarind trees (Tamarindus indicus), the nipa palms (Nipa fructicans) and coconut palm (Cocos nucifera). Tamarinds and nipa palms grow very well in brackish soils and the tamarind fruits and nipa leaves are saleable products. Coconut palms thrive well in sandy or lateritic soils.

Fauna

Vaas and Sachlan (1953) have listed the faunal elements commonly met with in brackishwater ponds. Crustaceans, such as cladocerans, ostracods, and copepods, are abundant and mysids and decapod larvae are very common. Even though there is an abundance of plankton it would appear that there is less utilization of zooplankton in these ponds, as plankton feeding animals are relatively few.

Among the macrofauna, the fishes are the most important. Besides cultivated fish several other brackishwater species of fish and economically important prawns and shrimps enter such ponds and provide a subsidiary income to the farmers. Juveniles and fry of these gain access with the tidal water. Species of Penaeus, Metapenaeus and Leander are the most common among these. The larval forms bury themselves in the muddy bottom and grow rapidly, feeding on the iliotrophic layer. Several species of Gobioid fishes can be seen on the muddy banks but they are of little economic value and are regarded as weed fish. It has been suggested that these and other economically unimportant species should be utilized as forage fish for culturing predatory species such as the cock-up.

The cock-up (Lates) and thread fins (Polynemus and Eleutheronema) and the ox-eyed herring (Megalops) are the common predatory fishes in brackishwater ponds. The cock-up and the ox-eyed herring, especially the former, feed voraciously on cultivated fish like mullet and milkfish and should therefore be kept out of the ponds as far as possible. The thread fins feed mostly on prawns and shrimps and are not so destructive as the cock-up. If the water fed into the ponds is properly screened it will be possible to restrict their entry. Different types of crabs are found in brackishwater ponds. Species of Scylla are of economic importance and fetch a good price. Other crabs such as Varuna and Saesarma are not of such value. These crabs dig holes in the embankments, weakening and eventually causing them to collapse, so too many of them are not desirable. Aquatic snakes are quite common and different types of birds live near the ponds. Otters and fish-eating birds prey on the fish. Mosquitoes, especially malaria transmitting species, are a serious menace in such areas.

Studies on the biotic interaction in Hawaiian and India brackishwater ponds have revealed that the dominant fauna are iliophagous. The benthic flora and detritus form the major item of their food. Several uneconomic species compete with the cultivated fishes for food. It is therefore essential to control the access of weed fishes effectively to render the conditions favorable for cultivated species. Selective stocking and proper screening of water supplies, as already mentioned, are necessary for preventing the entry of both predaceous and weed fish.

Preparation for Stocking

The general principles to be followed in the preparation of brackishwater ponds for stocking are essentially the same as for freshwater ponds. The first step is to ensure that the embankments are in good condition. Leaks can be stopped by digging a deep trench along the base and filling it with dry hard soil. Any undue decrease in the height of embankments must be made good. Most ponds are extensive and situated in areas which are not easily accessible, so intensive manuring is often either not possible or economically feasible. However, by regular draining and drying the pond bottom, as practised in Java and the Philippines, the fertility can be greatly enhanced. By this method it is possible to kill the predators in the ponds before stocking them with fish. Experiments indicate that drying raises the pH of the pond bottom, controls higher aquatic plants with heavy roots, reduces the concentration of bacterial parasites and enhances nitrogen fixation by blue-green algae and bacteria. In Java, green-manuring is practised to a limited extent, especially in the inland tambaks, where macro-vegetation, such as grass, is more easily available. The leaves of mangroves and other plants growing near the tambaks are distributed in small heaps over the pond bottom at the rate of about 1,500 kg per ha every three months. The soil has to be manured to stimulate the growth of Myxophyceae. In unfertile ponds two to three applications of green manure may be required to bring the fertility to a satisfactory level. The fish culturists in the Philippines often transplant algal growths and encourage them to thrive and multiply with small quantities of artificial nutrients. Green manure, which disintegrates rather slowly, will enrich the pond soil, and copra slime, applied at the rate of 450 to 900 kg per ha, has been found to be effective in enhancing the growth of blue-green algae.

More intensive pond preparation practices are followed in Taiwan. The method of preparing stocking ponds is the same as that for nursery ponds. After repeated draining, drying and proper fertilizing, stocking is done when there is 17 to 20 cm of water in the ponds. By this time a good growth of algae will have developed on the pond bottom. The ponds are drained, dried and fertilized again in August after moving the fish elsewhere.

The mullet culturists in Hong Kong also drain their ponds and manure them with rice bran, peanut cake, pig manure and night soil. Water is then run in and the ponds left for about two weeks before stocking with fingerlings.

Stocking

As already mentioned, milkfish is the most widely cultivated brackishwater fish. Mullets and prawns generally form subsidiary crops of some importance and, even though not intentionally stocked, they gain entrance into farms with the tidal water. In Java, tawes (Puntius javanicus) is stocked with milkfish in ponds having a salinity of 8 parts per thousand or less. Tawes has been observed to withstand salinities up to 22 ppt, but at such concentrations its growth may not be satisfactory. The presence of tawes is beneficial for the growth of the milkfish because they feed on coarse vegetation, including tough filamentous algae, grass and submerged plants, and pass out a good part of the food consumed in a semi-digested state. This is very acceptable food for milkfish which are unable to eat these plants in the raw state. Besides this, the droppings of tawes serve as a fertilizer and help the growth of myxophycean algae.

Tawes are introduced into a milkfish pond some time after the milkfish fingerlings. The stocking is generally done after the rains have started and the salinity has consequently decreased. No definite stocking rates appear to have been worked out. The number of fish is largely governed by the number of milkfish in the pond and the demand for the species in the area. Ordinarily, the stocking rate is adjusted to have 25 to 50 per cent tawes. In ponds containing large quantities of Chlorophyceae, there are possibilities of culturing tilapia along with milkfish. Intensive culture of tilapia has yielded very encouraging results in Malaya.

In Taiwan, besides mullets, the prawns, Penaeus carinatus and Penaeopsis monoceros, are collected from the sea with milkfish fry, or separately, and stocked in ponds with milkfish. To collect Penaeus fry, bunches of sea weeds are planted in shallow bays or inlets at distances of about 3.5 m. The young prawns that gather among the weeds are caught with a triangular dipnet. Fry of Penaeopsis are caught in the same type of dragnets used for milkfish fry. Penaeus prawns are generally grown in ponds for about six months until they reach a weight of 40 to 50 g, and Penaeopsis for a period of two to three months, until they attain a weight of 7 g each. In ponds of low salinity, common carp, grass carp, silver carp, big head and mud carp are also stocked with milkfish. As the carps' feeding habits are different from milkfish, there is not likely to be competition for food, and since they utilize food material not consumed by milkfish, and grow rapidly, the total yield of such farms is considerably improved. Grey mullet (Mugil cephalus) is cultured with the Chinese carps in Hong Kong.

In the fish farms of Hawaii and India, where stocking is generally done by admitting tidal water, several species of fishes and prawns get entry. The dominant species in Hawaiian fish ponds are the milkfish, grey mullet, tarpon (Megalops cyprinoides) and ten pounder (Elops indicus). Mullets, milkfish, pearl-spot and prawns are the main species in South India, whereas in East and West Bengal mullets, cock-up and prawns predominate.

Stocking may be done only once a year or up to three times depending on the fertility of the pond and the demand for small fish. Where small fish are not wanted, a longer culture period will have to be allowed.

The most intensive stocking procedure is followed in Taiwan where it is done thrice a year, the first in March, the second in April or May and the third in June. Fingerlings or yearlings, kept over in wintering ponds from the previous year, are stocked in March. In April and June, fresh fry or fingerlings are stocked. Fry stocked in June are transferred to wintering ponds and kept over for stocking the next year in March. The total number of fish planted is at the rate of 8,000 to 9,000 per hectare. The following table shows the stocking and fishing schedule:

	No. of fish planted per hectare	No. of fish removed per hectare
March	3000	--
April	5000	--
May	--	--
June	3000-4000	3000
July	--	--
August	--	--
September	--	5000
October	--	--

In the Philippines the maximum number of fingerlings stocked per hectare is 1,000 to 2,500 and in Indonesia about 1,500, where planting is done twice to three times a year. The stocking rate is, of course, modified according to the fertility of the pond, the availability of stocking

material and the personal experience of the farmer. For example, in the Porong type of ponds in Java the following stocking and fishing procedure is adopted (Schuster, 1952) and stocking and fish are often continued for long periods.

October	About 2,500 fry per hectare planted in the nursery ponds. The east monsoon crop remains in the deep sections of the farm.
November	Fry admitted into the stocking ponds, counting east monsoon crop and capture of marketable fish and prawns.
December	Catching part of the east monsoon crop. West monsoon crop admitted to the deep sections. Capture of prawns.
January	Capture and sale of east monsoon crop continued.
February	Repair work and deepening of channels.
March	Capture and sale of east monsoon crop and repair work continued. West monsoon crop counted.
April	Capture and sale of west monsoon crop, catching prawns. Preparation of nurseries.
May	Capture and sale of west monsoon crop continued. Planting 1,000 to 2,000 fry per hectare after deepening of central channels. Catching prawns.
June	Admitting east monsoon crop to stocking ponds. Catching prawns.
July	Mixing east monsoon and west monsoon crops. Catching prawns.
August	Capture and sale of the remaining west monsoon crop, leaving a few fish to grow to larger size. Catching prawns.
September	Preparation of nurseries and stocking ponds.

But in the inland tambaks of Java stocking is done only once a year. The fry planted in the nursery ponds in October are put into the stocking ponds in November. Besides cutting grass and other pond macro-vegetation to use as green manure, nothing is done until June when cropping is started. By August the ponds are completely fished and in September they are prepared for further stocking.

In the grey mullet ponds of Hong Kong, fingerling stocking is done from February to April and larger fish in the spring and autumn. Approximately 10,000 to 15,000 fingerlings (about 7.5 cm in length) of grey mullet and 1,000 to 2,000 fingerlings of Chinese carps are stocked per hectare of pond area. When the mullets grow to an average of about 140 g in weight (about five months after stocking) it is necessary to thin them to about 3,500 per hectare. The fish removed from the ponds can be used either for stocking other ponds or for sale.

Pond Management

The general principles of management of brackishwater fish ponds are the same as for fresh water, except perhaps the handling of water supplies. Regulated inundation and draining at definite intervals are essential. To hold the required depth of water the embankments, channels and sluice gates must be in good condition. Where the tides allow there is no difficulty in renewing and controlling a flow of water in the ponds, but on inland farms this may not be possible. In such cases the salinity of the pond water will probably increase steadily due to evaporation and seepage, especially during the hot months. Therefore a vigilant watch should be kept on the salinity and when it rises to a dangerous level the ponds should be flushed with fresh water.

Crabs and other burrowing animals that damage the embankments must be controlled by fishing, trapping and so forth. The various predatory and weed fishes must also be kept under control. If the ponds are drained regularly and undesirable fish kept out by close-meshed screens their numbers can be kept under control.

Snails, mainly of the genus Cerithidea, occur in Javanese fish ponds in such abundance as to become a pest. To a certain extent they compete with milkfish and mullets for food and they also use up the calcium content of the water for shell formation. Snails can be killed by molasses which also acts as a fertilizer and increases the growth of blue-green algae, but this method is not very economical because re-infestation takes place very quickly. Schuster (1952) remarks that when there is a thick layer of blue-green algae in a pond the snails disappear. Pond bottoms covered with jelly-like mud is also not conducive to their growth, whereas they thrive in liquid mud. This evidently shows that if ponds are properly manured and stocked with the optimum number of fish to maintain a good layer of algae, the chances of infestation by snails is greatly reduced.

The polychaete worm Eunice, which is abundant in brackishwater ponds, is also harmful to cultivated species like milkfish. They also make the pond soil porous and thus adversely affect its water-holding capacity. No effective control measures have been evolved as yet.

Although the young and adults of some of the extraneous fishes, such as Aplocheilus, Oryzias and Therapon, feed on mosquito larvae they do not keep this pest and the resulting malaria in check, in some areas. Studies conducted in Java have shown that Anopheles sundaicus breeds in ponds having a salinity between 2 and 20 parts per thousand and then only where the surface is covered with floating masses of algae or other vegetation. Maximum breeding takes place in algae-filled ponds with a salinity of 10 parts per thousand, although some species, such as A. subpictus, breed in waters as salty as 80 parts per thousand. In ponds cleared of Chlorophyceae, such as Chaetomorpha and Enteromorpha, little mosquito breeding takes place and if larvae do develop they are eaten by the always-present extraneous fish. As it has been established that milkfish can be grown on Myxophyceae alone and that the growth of Chlorophyceae can be controlled by periodical draining, it is possible to check the breeding of mosquitoes by keeping the ponds clear of green algae without adversely affecting the production of fish. Mosquito breeding generally takes place in shallow parts of ponds, so if the ponds are uniformly deepened mosquito breeding can be considerably minimized. Experimental work in Java seems to show that Chlorophyceae can be effectively checked by growing fish such as tilapia that feed on these algae.

The remarks made about controlling fish-eating birds and mammals when discussing the management of freshwater ponds, also apply here.

The presence of large quantities of organic matter on the pond bottom may result in the formation of poisonous gases like hydrogen sulphide and methane, which are injurious to fish life. If detected in time, this condition can be controlled by draining, drying and aerating the bottom soil.

Brackishwater ponds are relatively free from fish parasites. Even though some internal parasites occur in fish, hardly any of them are pathogenic. Schuster (1952) describes the only disease which has been recorded in the milkfish, namely "cold". When the water temperature suddenly falls the fish become lethargic and develop a milky discoloration of the skin, which after two or three days, peels off. During the period of attack the fish do not feed and therefore lose weight. Although mortality does not seem to be appreciable, it is probable that the fish become easy prey to predators at this time. In cold climates considerable mortality might take place if the milkfish are not transferred to wintering ponds.

The grey mullet in Hong Kong is affected by temperatures higher than 37°C. Shades will protect them from the hot sun, but should deaths occur, further mortality can be arrested by running colder water into the pond.

Foods and Feeding

While intensive artificial feeding is a common practice in freshwater ponds, it is not common in brackishwater fish ponds, mainly because of their size and the fact that the large quantities of foods necessary are not easily available at economical prices. Algae form the most important food in milkfish and mullet ponds and the farmer always tries to maintain a good growth of them. Blue-green algae are eaten by the milkfish until they are about 20 cm in length and thereafter they are also able to feed on soft green algae. Young mullet fry feed on planktonic organisms but fingerlings sustain themselves on algae. The composition of the blue-green algae, Oscillatoria spp. and Phormidium spp., is given below; they are more nutritious than green algae.

Dietetic composition of blue-green algae in g per 1,000 g of wet algae:

Composition	Proportion
Water	829.0
Raw protein	16.5
Fat	3.9
Nitrogen-free matter	13.7
Raw fiber	14.6
Ash	122.3 of which 32.9% is SiO_2
	1,000.0

When the production of algae in a pond is not sufficient to feed the fish, Philippine farmers collect algae from other water areas and put them in the ponds. Besides algae, hydrophytic plants, such as Ruppia, Najas and Halophila, which are locally known by the collective name digman, water hyacinth (Eichhornia crassipes) and paddy straw are collected and fed in a decayed or dried form.

Another method of obtaining adequate supplies of algae is by cultivating them in separate ponds. Special "collectors", such as twigs of mangroves and bamboo poles, are fixed in the ponds and algae spores attach themselves to and grow on these "collectors". The algae are taken to the stocking ponds as and when needed. Recent experiments conducted in the Philippines have shown that the seaweed Gracilaria is a very suitable food for fingerlings and adult milkfish. The food values of this weed and of other plants are shown in the following table:

Food constituents of certain algae and weeds

Name	Moisture %	Ash %		Fat %		Protein %		Carbohydrates %	
		F*	D**	F	D	F	D	F	D
Gracilaria confervoides	6.92	15.31	16.48	0.4	-	11.98	12.89	65.39	70.63
Enteromorpha intestinalis	81.35	6.02	32.27	0.48	2.57	3.66	19.61	8.49	45.55
Chaetomorpha spp.	85.50	2.82	19.50	0.27	0.71	3.72	27.66	7.87	52.13
Cladophora spp.	57.20	9.90	23.16	0.84	1.96	5.16	12.07	26.90	62.81
Eichhornia crassipes	89.81	1.34	13.15	-	-	2.19	21.49	6.66	65.36

*F - Fresh **D - Dry

The weeds are scattered in such a way as to form a carpet of a uniform thickness of about 15 cm on the pond bottom. In many ponds in the Philippine Islands milkfish are now grown to marketable size fed almost entirely on Gracilaria. The required quantity of weed is introduced before stocking the ponds or it is fed in small lots throughout the period of growth. The quantity required to feed a given number of fish has yet to be established but it usually ranges between 200 and 500 kg per ha. One disadvantage of depending entirely on this weed for milkfish is that it does not provide any shade from the sun as the weeds remain at the bottom. To remedy this, the fish culturists increase the water level in the ponds as much as possible during the summer months; this does not in any way affect the growth of Gracilaria. Salinities lower than 5 ppt have an adverse effect on the weed and so their use is limited to ponds in which the salinity never falls below that level. With the use of Gracilaria as food for milkfish it has now become possible to increase the number of crops from a pond and to stock as many as 3,000 fish per hectare.

Rice bran is a suitable artificial food for milkfish and mullets. Small quantities of rice bran are generally fed to mullets in India and the Philippines, but intensive artificial feeding is done mainly in Taiwan and to some extent in Hong Kong. As already stated, the farmers in Taiwan use rice bran as a manure for the ponds, and in the early stages of growth there is a considerable quantity of rice bran for the fry or fingerlings to feed on directly. Intensive artificial feeding starts in May and only rice bran is given to the fingerlings until June, as it is believed that they are not able to feed on coarser food at this stage. By the time the rainy season sets in the salinity of the water in the ponds decreases and the natural food supplies greatly diminish. Because of the lower salinity, a sufficiently thick growth of algae does not appear. Rice bran and soya bean cake, broken into small pieces, are fed during this period. In July, August and September peanut meal is also added to the rations as it is believed that this stimulates the appetite of the fish and hastens its growth. The quantity of artificial foods necessary for one hectare of pond area is about 2,000 kg of rice bran, 500 kg of soyabean cake and 36 kg of peanut meal. The following table shows the feeding rates and the kinds of artificial foods given to grey mullet and carp in brackishwater ponds in Hong Kong. No allowance has been made in it for mortality, and when the number of fish in the pond decreases due to deaths, a proportionate reduction in the quantity of food supplied is necessary. Besides these foods, rice bran, peanut cake, pig manure and night soil are put into the ponds at intervals of two to three days; these are partly consumed directly as food and act partly as fertilizers.

Feeding Schedule for Milkfish Ponds in Hong Kong

Number of days after stocking	Food per ha	Average daily ration in kg
1 - 10	-	-
11 - 30	Rice bran	1.0 - 1.5
31 - 60	Rice bran	1.5 - 3.0
61 - 90	(Rice bran	3 - 5
	(Peanut cake	1 - 3
91 - 150	Rice bran)	5 - 8
	Peanut cake)	3 - 8
151 - 210	Rice bran	8 - 12
	Peanut cake	8 - 14
211 - 300	Rice bran)	12 - 16
	Peanut cake)	19 - 24

In Taiwan, Java, and the Philippines, where two to three crops of milkfish are raised every year, the fish are seldom allowed to grow to a large size. In Taiwan, when they are caught for sale, the fish weigh 150 to 300 g and the rate of mortality ranges from 8 per cent to 20 per cent. During winter the water temperature may fall to 10°C and the growth of the fish is greatly decreased. In the Philippines, when the fish are caught at the end of 6 to 9 months, they have reached an average weight of 400 g and the estimated mortality is 50 per cent to 70 per cent. In Indonesian ponds, where the growing period ranges from 6 to 10 months, they are caught when they attain an average weight of 350 g. The mortality might be 50 to 80 per cent.

Capture and Marketing

Methods of Catching

Partial harvesting is done in many ponds for a major part of the year. It is not always possible to drain the ponds to catch the fish, but the water level can be considerably reduced by shutting off the supply for a few days before fishing is done. Drag nets of various lengths and depths, depending on the pond dimensions, can be used. In Java, a number of fishermen wade through the pond in a row, using cast nets.

The tendency of adult milkfish and grey mullet to swim against the current is taken advantage of to capture them. Water is taken in through the sluice gates at high tide, the fish swim against the current and gather near the sluices, making frantic efforts to escape, where it is easy to capture large numbers with nets. If the deep area adjacent to the sluice gate is made into a "catching pond", as is done in the Philippines and in Indonesia, all the fish swimming against the current can be trapped by closing its entrance from the stocking ponds. A deep channel or "fish race" will also serve the purpose equally well. When the fish are thus enclosed it is easy to catch them with nets. This type of capture has been developed to a considerable extent in the Philippines where "catching ponds" with several compartments are sometimes used for the purpose. The fish entering the "catching ponds" are held over at least 24 hours before removal so that their guts will be cleared of all food consumed. This is done to improve their keeping qualities.

Use is often made of bamboo gratings for catching milkfish from ponds in Java. The area is dragged with a rectangular grating, the fishermen using hands and feet to push it and the fish are thereby enclosed near the pond outlet from where they are removed with dip nets.

Different types of nets and traps are used for catching prawns and shrimps. These generally swim in the direction of the current. Shrimps are often collected by operating a long-handled net against the current. Or, when draining the pond, they are caught in a small purse net fixed to the sluice gate.

Prawns have a tendency to move along the sides of embankments and this habit is taken advantage of to capture them by fixing bamboo screens in the pond bed at right angles to the embankments. The catches can be increased with lure lamps hung over the traps. Prawns are also caught by running the pond water through a pipe with a trap fixed at the outlet end.

The atols in front of sluice gates in the bheris of Bengal catch fish and prawns. Baited lines are widely used for catching crabs, and hooked tools to catch burrowing eel-like fishes and crabs from holes in the embankments.

Marketing

As most brackishwater ponds are situated away from towns where the major part of the produce is marketed, there is need for ice as a preservative for fish and prawns, but crabs can generally be transported alive. Boats and trucks are used to carry the catch to the markets.

When ice is not available the fish farmers in Java boil milkfish in strong brine with a few roots of Curcuma domestica. The spice imparts a bright yellow color to the product which is greatly favored by consumers, and fetches a better price than fresh fish.

A special method of curing is practised in certain parts of Java. Earthen pots about 25 cm wide and 30 cm high are filled above the brim with fish arranged in layers. Brine is then poured to 5 cm below the top and the pots are heated until the brine has boiled down to half its original quantity, and then drained off and some dry salt added. After heating again for a few minutes the pots are covered with leaves and tied. This process needs great skill and care. The cured fish keeps for about three months. The boiled brine contains fish juice and when the liquid is evaporated over a fire a paste, known as petis, is left which commands a good market among Indonesians.

Prawns are cured in the same way.

Smoking milkfish has now become fairly common and it has been found that by adding a small quantity of potassium nitrate and by carefully regulating the heat, the whitish crust that often develops on the fish during smoking can be avoided. Other processes of curing and drying can be adopted, depending on consumer preferences and demand.

Marketing

The marketing arrangements will, of course, depend on the magnitude of the supplies. In the tambak area of Java, which is situated far away from trade and cultural centers, pedlars barter rice and other provisions in return for fish, prawns, shrimps, etc. When there are a large number of ponds in an area, it will be possible to organize cooperative marketing, and thus reduce overhead expenses, such as transport, and to ensure that catches are sold in a more satisfactory condition.

Economics

In assessing the economics of brackishwater fish culture the fact that it generally is only a stage in the reclamation of waste lands for agriculture has to be taken into consideration. While no income may be available to the farmer during the period of reclamation, he is able to derive a substantial income by utilizing the area for fish culture and to produce food for himself and his family.

The construction of embankments, sluice gates, excavation of the pond site and the like, involve an initial outlay of considerable sums of money, depending on the cost of labor in the area, but a major part of this expenditure has to be incurred for reclamation, even if the land is not used for fish culture. When milkfish are cultured the fry have generally to be bought from dealers and this is a recurring expenditure. Fry of grey mullets, prawns and other species are usually available in the vicinity of the farms in areas where they are cultured, and can usually be easily collected. Artificial feeding and pond manuring is seldom done on a large scale. But when manure is applied it usually consists of the grass and mangrove leaves collected from the embankments or marginal areas. In view of this the total investment as such in brackishwater fish culture is very small. It should, however, be stressed that by investing a little more than is now done and intensifying the operations the income can be considerably increased, as has been shown in Taiwan.

One great advantage of brackishwater fish farming is that the farmer does not have to wait until the end of the year or for a couple of years to get some income. On the contrary, right from the stage of constructing the pond he will be able to get an income by selling mangrove stems for fuel, bark for tanning fishing nets and leather, birds eggs that may be collected from the area, lizard and snake skins and so on, depending on the enterprise of the farmer. The leaves of the nipa palm cut from the pond site will also fetch a good price. Once the farm has been constructed and fish culture operations begun, fishing for extraneous fishes and prawns is soon started. The embankments of brackishwater ponds are often suited for cultivating economically important plants. Besides preventing soil erosion and providing leaves for green manuring, some of these can be eaten and others sold. In the Sunderban area of West Bengal the fish farmers cultivate paddy in adjacent fields that have been reclaimed for the purpose. Salt making by sun drying is also undertaken when the conditions are suitable. Thus it is evident that a farmer with the necessary capital can have a number of profitable side lines on his land. Further, such farms give employment to more people. Industries such as metal box, net and implement factories, fish curers and canners benefit from the activities of fish farmers. Transport services also derive profits from the trade in fish. A certain amount of cooperation among the fish farmers in the matter of help in times of emergency and financial strain exists at present, but there is ample scope for the organization of the entire industry on sound co-operative lines.

In view of the peculiar conditions that exist it is often difficult to assess with any degree of accuracy the production from brackishwater ponds. On an average about 10 per cent of each farm consists of very shallow areas that do not contribute in any large measure to its productivity, and only about 73 per cent of the area is of direct significance in this respect. As already mentioned in a previous chapter, the production of fish in a pond will depend to a large extent on the type of soil. Schuster (1952) has given the following as the average production of milkfish in brackishwater ponds in Java.

Production of Ponds in Java

Soil type of ponds	Production in kg per ha
Juvenile volcanic soil	250 - 450
Colloidal clay	200 - 350
Juvenile lateritic soil	150 - 300
Calcareous clay	100 - 150
Senile lateritic soil	80 - 120
Rocky or sandy soil	50 - 80

The yield of prawns and shrimps varies from 25 to 80 kg and of other extraneous fishes, 16 to 35 kg per ha.

In the Philippines a production of 350 to 750 kg of milkfish is obtained when only one crop is raised. In Taiwan where the most intensive culture of milkfish is carried out the production is 1,000 to 2,000 kg per ha. In slightly brackishwater ponds in Hong Kong, an average of 1,500 kg of mullets and 1,000 kg of carps are produced per hectare of pond area.

The profit that a farmer can get out of brackishwater fish culture is dependent on so many factors that it is impossible to generalize on it. Based on the statistics collected on the operation of such ponds in Java, the following figures of receipts and expenditure have been compiled:

Receipts and Expenditure of Ponds in Java in Percent

Receipts (Percentage of total)		Expenditure (Percentage of total)	
Milkfish sold	70	Purchase of fry	5 - 20
Prawns sold	20	Maintenance of ponds	8 - 25
Extraneous fish sold	5	Miscellaneous	1 - 5
By-products sold	5	Land rent	3 - 7
		Caretaker's share*	25 - 35
		Owner's profit	58 - 8

* In Java, very often the pond owner does not himself culture fish but a "caretaker" does the work on a share basis.

Owners of brackishwater farms sometimes lease them out for short periods. This adversely affects the productivity of the ponds as the lessees are generally interested only in getting the maximum return in the period and do not pay sufficient attention to the maintenance of the farm and its installations. In Taiwan, where the ponds are small, a fish farmer and his family are usually able to operate one to two hectares of milkfish ponds. He may own the ponds, take them on lease from the landlord or work on the farms as an employee. Under conditions existing in Taiwan the financial gain from such ponds is quite considerable, in spite of the large amounts that have to be spent on fish poisons, fertilizers, artificial foods, etc. The following figures of receipts and expenditure relating to every hectare of pond area in the Kangshan Fish Culture Cooperative (1952) is of interest in this context.

Receipts and Expenditure of Ponds in Taiwan

Receipts in Taiwan dollars *			Expenditure in Taiwan dollars	
Sale of fish from the first crop	(540 kg)	3,429	Stocking material (1,200 kg)	2,400
" " " " the second crop	(780 kg)	4,680	Rice bran (3,000 kg)	1,800
Extraneous fishes and prawns	(150 kg)	315	Peanut meal (720 kg)	612
			Tea seed meal (180 kg)	257
			Depreciation of nets and gear	118
			Repair and improvement work	240
	Total:	8,424	Total:	5,427

* About 23 Taiwan dollars equal 1 U.S. dollar.

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